

# TRANSACTIONS

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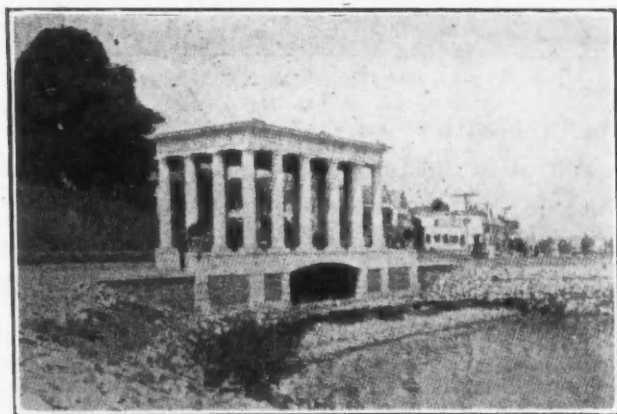
No. 1

## HISTORICAL NEW ENGLAND

### PLYMOUTH AND THE SOUTH SHORE

PERHAPS one of the most interesting trips out of Boston is the one to Plymouth, the landing place of the Pilgrim fathers. This trip takes us southward from Boston, following the South Shore, over a distance of approximately 100 miles.

Leaving Boston at Neponset Bridge, one approaches the Pilgrim Boulevard and the Quincy Shore Reservation of the Metro-



Plymouth Rock and Canopy

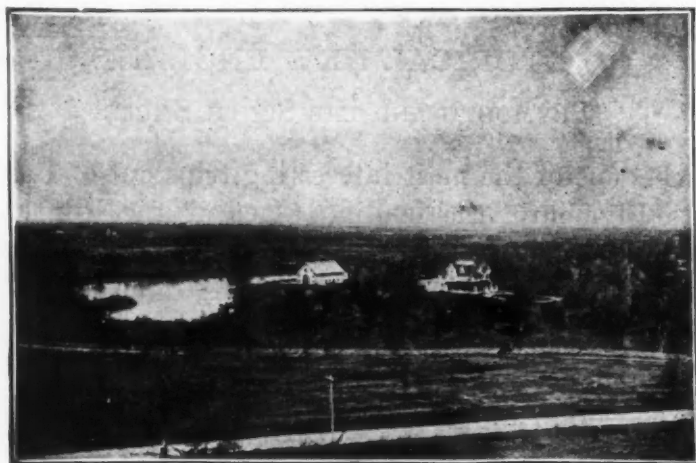
politan Parks system. This is a direct route to Squantum, Wollaston Beach, historic Merrymount, Hough's Neck, and Nantasket. Attractive clubhouses of well-known yacht clubs are on Wollaston Beach and Hough's Neck.

Cohasset has an irregularly rocky coast, commanding a wide extent of ocean prospect. On and about its renowned Jerusalem Road are numerous extensive estates with elaborate houses and

grounds. The granite lighthouse seen rising from the ocean is Minot's Light.

Seituate also enjoys a beautiful ocean front with fair beaches and a pretty harbor, protected by rocky cliffs. This town is the scene of Samuel Woodworth's lyric, "The Old Oaken Bucket."

Marshfield was the country home of Daniel Webster. The Webster place originally included a part of "Careswell," the



Home of Daniel Webster

domain of the Plymouth Colony governor, Edward Winslow. Half a mile back from it is the tomb of Webster, with the epitaph which he dictated the day before his death (October 24, 1852).

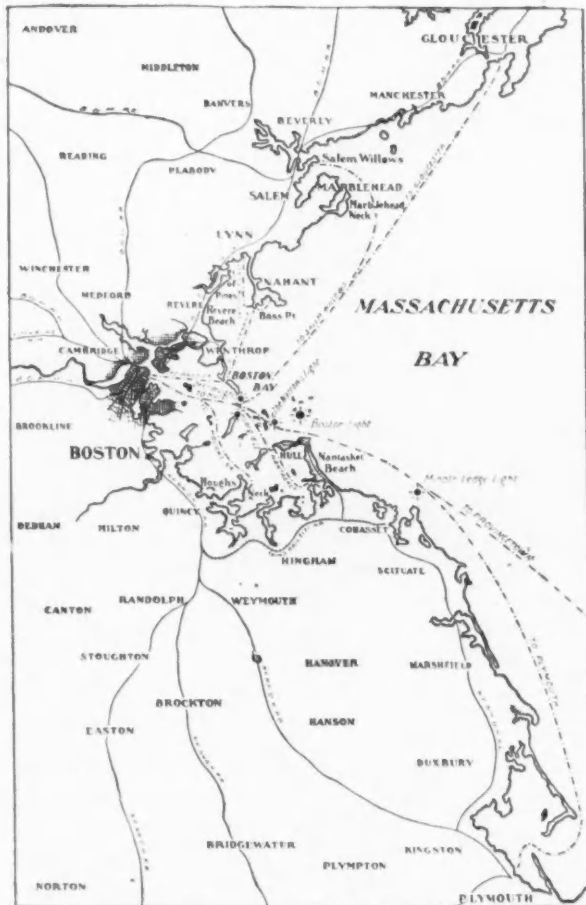
Duxbury, the home of Elder Brewster, Miles Standish and John and Priscilla Alden, is marked by the Standish monument on Captain's Hill, which looms up in the landscape, visible in a wide extent of country round about. In about the middle of the village is the oldest of its burying grounds, and the supposed grave of Standish is marked by a monument. Here are also graves of the Alden family, and possibly the grave of Elder Brewster.

Kingston, a part of Plymouth till 1726, is a typical old colony town, with a cheerful air of substantiality.

Marked changes have come to Plymouth, in connection with the celebration (December 21st, 1920) of the three hundredth anniversary of the landing of the Pilgrims. Plymouth Rock, itself, on which the followers of Bradford stepped, has been reset in its original place and a fitting memorial now protects the unusual



landmark. Especially along the waterfront, formerly disfigured by wharves, are well planned improvements commemorating the founding of the first permanent settlement in New England. Cole's Hill, where the first rude houses were built, has been transformed



Massachusetts Bay and  
Shore Line

into a wooded park suggestive of the topography of the region three hundred years ago. Pilgrim Hall, near the town center, is the repository of Pilgrim antiquities. The collection includes the sword of Miles Standish, and the chairs of Elder Brewster and Governor Bradford. The collection of paintings and prints and other historical objects is of great interest and value. In the County Courthouse are documents of Pilgrim days, including papers containing signatures of Bradford and Standish. Leyden Street, the first and chief Pilgrim street, leads to Burial Hill.

Here were the first forts which served also as meeting houses. There are many graves here of the early settlers; conspicuous among them is that of Governor Bradford. The Old Powder Magazine has recently been restored. Watson's Hill, where the



Forefathers' Monument

first Indians appeared to the colonists, and whence came the friendly Samoset, and after him Massasoit, lies to the southward of Burial Hill. Below is seen the Town Brook Crossing, where Massasoit and his braves were met by the Puritan leaders, from which

meeting resulted the "Famous League of Peace." To the north of the town, built on a hill commanding a fine view of the harbor, is Forefathers' Monument, made from plans originally designed by Hammett Billings, the sculptor. On the main pedestal stands a figure of Faith, the largest and finest piece of granite statuary in the world. On the projecting pedestal are seated figures emblematic of the principles upon which the Pilgrims proposed to found their commonwealth. On the faces of the projecting pedestals are also reliefs of the Embarkation, Signing of the Compact, the Landing, and the Treaty with the Indians.

Beyond Plymouth, Cape Cod, dotted with well-known summer resorts, stretches a curved arm into the Atlantic. At the tip of the Cape is Provincetown, where the Pilgrims landed on their way to Plymouth, November 11, 1620. The Pilgrim Monument, here dedicated in 1910, is a conspicuous sea mark for mariners.

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### HOTEL ACCOMMODATIONS FOR THE BOSTON CONVENTION

THE MATTER of hotel accommodations during the time of the next annual convention in Boston is an important consideration for all of our members and guests. The Copley Plaza will be the headquarters of the Society, and even at this early date we have been advised that all of their facilities have been reserved for the week of the convention. It will be necessary therefore for those who have not made their reservations, to select some hotel other than the Copley Plaza.

It is essential and advisable that hotel reservations be made immediately, and members are requested to send their reservations directly to the manager of the hotel at which he wishes to be located, stating time of arrival, kind of accommodations desired, and the price he desires to pay. It is further advisable that the hotel management be requested to acknowledge receipt of each reservation.

By referring to the following list of hotels it will be an easy matter to make a selection. It will be noted that the hotels are listed in accordance with their nearness to Copley Square, the site of the Copley Plaza. The final tabulation gives the distances of

each of these hotels from the convention headquarters, and likewise the distance of each of these hotels from Commonwealth Pier, where the exposition will be held.

### List of Boston Hotels\*

(Listed in order of nearness to Copley Square)

#### COPLEY PLAZA

1 person, with bath, inside.....	\$ 5.00 to \$ 6.00
1 person, with bath, outside.....	8.00 to 10.00
2 persons, with bath, inside.....	8.00
2 persons, with bath, outside.....	11.00 to 15.00



Copley Plaza  
(Convention Headquarters)

#### WESTMINSTER

1 person, with bath.....	3.50	
2 persons, with bath.....	6.00 to	7.00
4 persons, with bath, suites.....	12.00	

#### BRUNSWICK

1 person, without bath, with running water....	2.50 to	3.50
1 person, with bath.....	4.00 to	5.00
2 persons, without bath, with running water...	5.00	
2 persons, with bath.....	6.00 to	8.00
4 persons, with bath, suites per person.....	3.00	

#### LENOX

1 person, without bath, with running water....	3.00 to	3.50
1 person, with bath.....	4.00 to	6.00
2 persons, without bath, with running water...	4.00 to	5.00
2 persons, with bath.....	5.00 to	8.00
4 persons, with bath, suites.....	12.00	

\*All European plan except as otherwise stated.

## VENDOME

## EUROPEAN PLAN

1 person, with bath.....	3.50 and up
2 persons, with bath.....	5.00 and up
1 person, with bath, sitting room chamber....	5.00 and up
2 persons, with bath, sitting room chamber....	7.00 and up

## AMERICAN PLAN

1 person, with bath.....	7.00 and up
2 persons, with bath.....	13.00 and up
1 person, with bath, sitting room chamber....	11.00 to 16.00
2 persons, with bath, sitting room chamber....	15.00 to 20.00

## ARLINGTON

1 person, with bath.....	3.00
2 persons, with bath.....	4.00



The Lenox



The Brunswick

## TOURNAINE

1 person, with bath.....	5.50 to 7.50
2 persons, with bath.....	8.00 to 10.50

## ADAMS HOUSE

1 person, without bath.....	2.50 to 3.50
1 person, with bath.....	4.50 to 6.00
2 persons, without bath.....	4.00 to 5.50
2 persons, with bath.....	6.50 to 10.00

## SOMERSET

1 person, without bath.....	4.00
1 person, with bath.....	5.00 to 7.00
2 persons, without bath.....	5.00
2 persons, with bath.....	6.00 to 8.00
4 persons, with bath.....	10.00 to 12.00

## AVERY

2 persons, with bath.....	5.50 to 6.50
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## PARKER HOUSE

1 person, without bath.....	2.50 to 3.50
1 person, with bath.....	3.50 to 6.00
2 persons, without bath.....	4.00 to 5.50
2 persons, with bath.....	5.50 to 8.50

## BELLEVUE

2 persons, without bath.....	5.00 to	6.00
2 persons, with bath.....	8.00 to	12.00

## YOUNG'S HOTEL

1 person, without bath.....	1.75 and up	
1 person, with bath.....	3.50 and up	
2 persons, without bath.....	4.00 and up	
2 persons, with bath.....	6.00 and up	

## ESSEX

1 person, without bath.....	2.50 to	3.50
1 person, with bath.....	3.50 to	5.00
2 persons, without bath.....	4.00 to	5.00
2 persons, with bath.....	6.50 to	8.00

## UNITED STATES HOTEL

1 person, without bath, with running water....	2.00 to	2.50
2 persons, without bath, with running water...	4.00 to	4.50
1 person, with bath.....	3.00 to	4.00
2 persons, with bath.....	5.00 to	6.00
2 persons, with bath, suites.....	6.50	
3 persons, with bath, suites.....	7.75	
4 persons, with bath, suites.....	9.00	

## COMMONWEALTH

2 persons, without bath.....	4.50	
2 persons, with bath.....	5.50	

## BOSTON TAVERN

1 person, without bath.....	2.00 to	2.50
2 persons, without bath.....	3.50	
2 persons, with bath.....	5.00	

## HEALY'S

1 person, without bath.....	3.00	
1 person, with bath.....	3.50	
2 persons, without bath.....	4.50 to	5.00
2 persons, with bath.....	5.00 to	6.00

## AMERICAN HOUSE

1 person, with bath, with running water.....	2.25 to	2.50
2 persons, without bath, with running water...	4.00	
4 persons, without bath, with running water...	5.50 to	6.50
2 persons, with bath.....	5.00 to	6.00
2 persons, with bath, suites.....	8.00	

## QUINCY HOUSE

1 person, without bath.....	2.00	
1 person, without bath, with running water....	2.50	
1 person, with bath.....	3.00 to	4.00
2 persons, without bath, with running water...	4.00	
2 persons, with bath.....	5.00 to	7.00



**List of Hotels Showing Their Location in Respect to Copley Square and Commonwealth Pier**

<i>Hotel</i>	<i>Number Rooms</i>	<i>Distance from Head- quarters. Miles</i>	<i>Distance from Ex- position. Miles</i>	<i>Address</i>
Copley-Plaza . . . . .	500	0.0	2.25	Copley Square
Westminster . . . . .	250	0.0	2.25	Copley Square
Brunswick . . . . .	275	0.25	2.25	Boylston & Clarendon Sts.
Lenox . . . . .	200	0.25	2.25	Exeter St.
Vendome . . . . .	250	0.25	2.25	Commonwealth Ave.
Arlington . . . . .	300	0.50	1.5	Arlington Sq. & Chandler St.
Touraine . . . . .	225	0.75	1.75	Tremont & Boylston Sts.
Adams House . . . . .	460	0.75	1.75	555 Washington St.
Somerset . . . . .	300	0.75	3.00	Commonwealth Ave.
Avery . . . . .	150	0.75	1.75	Washington & Avery Sts.
Parker House . . . . .	321	1.00	1.25	Tremont & School Sts.
Bellevue . . . . .	250	0.75	1.5	Beacon Hill
Young's . . . . .	200	1.00	1.25	Court & City Hall Sts.
Essex . . . . .	300	1.00	0.75	Atlantic Ave. & Essex St.
United States . . . . .	250	1.00	1.00	Essex St.
Commonwealth . . . . .	210	1.00	1.00	Bowdoin St., Beacon Hill
Boston Tavern . . . . .	125	1.00	1.25	347 Washington St.
Healy's . . . . .	75	0.75	1.75	642 Washington St.
American House . . . . .	275	1.25	1.5	56 Hanover St.
Quincy House . . . . .	500	1.25	1.5	Brattle St.

## MINUTES OF MEETING OF THE BOARD OF DIRECTORS

LECLAIRE HOTEL, MOLINE, ILLINOIS  
THURSDAY, MAY 22ND, 1924, 3:00 P. M.

UPON motion properly made, seconded and carried, the minutes of the previous meeting (Rochester, N. Y., January 31, 1924) were approved without reading, inasmuch as the members of the Board had previously had copies of the minutes for observation.

The petition for a chapter of the Society in San Francisco and vicinity to be known as the Golden Gate chapter was presented, signed by 102 individuals. A previous letter ballot to the Board had granted a temporary charter and so upon motion properly made and seconded, it was unanimously carried that a charter for the Golden Gate chapter should be granted.

The treasurer then submitted an unaudited financial statement for the first three months of the fiscal year, to be published in the

June issue of the TRANSACTIONS. The report was accepted. (See page 548 of June TRANSACTIONS.)

It was moved, seconded and unanimously carried that it was the sentiment of the Board of Directors to recommend to the Finance Committee that provision be made, if possible, for re-investment of interest from present investments of the Society in Government securities.

In order to comply with the provisions of the new Constitution, a form was submitted for credentials of members of the National Nominating Committee, this form to be filled out in duplicate, one copy to be forwarded to the National office and the other to be presented by the chapter representative at the meeting of the Nominating Committee. Upon motion properly made and seconded, it was unanimously carried that the form printed below be approved and adopted.

The undersigned Chairman and Secretary, respectively, of the ..... Chapter of the American Society for Steel Treating, in accord with Section 4 (a), Article IX, of the Constitution of that Society, do hereby certify:—

Members

That, at a meeting of the Executive Committee of that  
(Erase one)

Chapter, duly called and held, on the ..... day of  
....., 19...., the following were regularly  
designated to represent that Chapter on the National Nominating  
Committee for the year 19....

Representative .....

Alternate .....

In witness whereof we have hereunto set our hands this  
..... day of ....., 19....

.....  
Chairman

.....  
Secretary

The budget for proposed expenditures of the Boston Committee for the 1924 Convention was submitted and given consideration. Upon motion properly made, seconded and unanimously carried, it was agreed that the National Society should contribute the sum of \$4,000.00 to the Boston Committee, this to be exclusive of any assistance the committee might receive from the City of Boston.

Consideration was then given to the selection of a convention

city for 1925. This subject was given consideration at this time, due to the fact that with the adoption of the new constitution, the present Board of Directors will remain in office until January 1st, 1925, and the selection of a convention city would consequently rest with the present Board of Directors. An invitation was presented from the Cleveland chapter and from the Cleveland Chamber of Commerce, to hold the 1925 Convention and Exposition of the Society in Cleveland, offering them unlimited hotel facilities, as well as the use of the new ten million dollar convention hall for the Exposition. After due consideration, it was moved, seconded and unanimously carried, that Cleveland be selected as the city for the 1925 Convention and Exposition, and that the dates should be September 14th to 18th inclusive, 1925.

J. F. Harper, chairman of the Recommended Practice Committee, presented a report covering the activities of this committee, as well as a report on the data sheets of the A. S. S. T. Handbook. Upon motion properly made, seconded and unanimously carried, the report was accepted.

Consideration was then given to the supplying of data sheets already published, to new members of the Society, free of charge. This policy has been followed since December, 1923, when the first sheets were issued. It was moved, seconded and unanimously carried that after July 1st, 1924, no further free distribution of back data sheets should be made, but that the newly elected member shall be privileged to purchase such previously published sheets as he desires, at the rate of 5 cents per sheet. It is understood, however, that the new member receives free of charge the data sheets issued during the time covered by his membership.

The secretary was authorized to extend to the officers of the Tri City chapter and to the various manufacturing industries in that community, the appreciation of the Board for their valuable services in the successful conduct of the spring sectional meeting of the Society.

All officers and directors were present except Dr. Zay Jeffries, Treasurer.

The meeting adjourned at 5:30 p. m.

### A DUTY TO OURSELVES

**E**VERY individual has certain duties that he owes to himself. Our life is made up quite generally of duties to our family and to our country.

Among the duties one owes to his family must be considered preparation of one's self to give the maximum service in any situation which may arise. Service, loyal service in every instance, has its own reward. It is a factor that is appreciated more than any other contribution one may make. In order to give efficient, loyal service it is necessary to prepare one's self. Perhaps too many individuals are found who are accustomed to accept life as it is without making any serious effort to improve themselves or accept opportunities for such improvement.

An exceptional opportunity for self improvement and advancement as a preliminary preparation for efficient service is found in the annual convention of the A. S. S. T. When 65 per cent of the members of the Society accepted the privilege of attending the convention last year, they did much to stamp the organization of which they are members as one holding out opportunities for increased knowledge and improvement. It has been stated on good authority that this record of attendance has never been paralleled in the history of any technical organization. It is impossible to inquire of any individual who attended the convention in Pittsburgh and not learn from him that the benefits derived therefrom were of greatest importance, usefulness and inspiration in his activities.

The Annual Convention and International Steel Exposition of the A. S. S. T. are two of the greatest services performed by the Society. They will bring together in Boston in September the keenest minds in the industry to present and discuss, the important problems confronting the profession. While one might say that it is possible to read the papers and discussions later, as they are printed in *TRANSACTIONS*, it must be realized that the personal contact forms an important link in the chain of progress. In attending the convention you will come back to your work with renewed vigor and a greater insight into the problems that present themselves. So let us urge that you make your preparations now, to attend.

# QUENCHING PROPERTIES OF GLYCERIN AND ITS WATER SOLUTIONS

BY HOWARD SCOTT

## Abstract

*The cooling power of glycerin and its water solutions as well as that of an oil-water emulsion was examined for the purpose of finding quenching media to span the gap between water and oil. From experimental quenching curves giving the rate of cooling at the center of a 1-inch diameter cylinder of 32 per cent nickel steel, an alloy showing no transformations, but having approximately the same thermal properties as austenitic high-carbon steel, it is shown that glycerin-water solutions accomplish this purpose effectively and, moreover, have characteristics distinctive from those of oil, which are apparently in their favor.*

*The observations on the cooling rates of the baths were confirmed by observations of the hardening of deep-hardening steel in the several baths. The hardness of these steels, measured by the scleroscope and Rockwell tests, increased definitely with the cooling rate, and the higher hardness of the faster cooled steels was maintained on tempering below 300 degrees Cent. (572 degrees Fahr.)*

*By mathematical analysis of the results, the cooling constants of the several baths were approximately evaluated and curves plotted from which the cooling rate at the center, and temperature gradients from center to convex surface of long cylinders of any diameter can be estimated under certain limitations.*

## INTRODUCTION

FOR hardening steel by quenching, the liquids, oil and water, are used almost universally. There is, however, a wide gap in the range of quenching power between that of water and of commercial quenching oils. If suitable quenching media can be found having quenching powers within this range, some refinements in the technique of hardening should be possible. Concentrated sulphuric acid has an intermediate cooling power, but is unsuitable for general use because of its dangerous nature. A common ex-

\*Published by permission of the Director of the U. S. Bureau of Standards.

Acknowledgment is made to S. S. Kingsbury for his effective assistance in this experimental work.

The author is physicist, Bureau of Standards, Washington, D. C.



pedient is to use water heated to a suitable temperature. This method is not trustworthy, inasmuch as the cooling rate rapidly changes with small variations in the water temperature as the boiling point is approached.<sup>1</sup> Two other possible means have been suggested for obtaining intermediate quenching rates. One is to use an emulsion of oil and water and the other to use solutions of glycerin and water. An account of tests of these proposals is the purpose of this paper. Tests of the emulsion used did not confirm the inference that it would be intermediate in quenching power between its constituents. On the other hand the glycerin-water solutions of various concentrations were found to give the desired range of cooling rates. These media have, moreover, other distinguishing properties than the cooling power at high temperatures, which are of special interest.

#### QUENCHING EXPERIMENTS

To compare the cooling properties of the media proposed, a very simple experimental device was used. A thermocouple of 0.014 inch diameter wire was mounted in a hole  $\frac{1}{8}$  inch diameter bored 2 inches deep in the center of a cylinder of 32 per cent nickel steel, 1 inch in diameter and 4 inches long. The hot-junction of the thermocouple was forced into metallic contact with the bottom of the hole by a snugly fitted plug, and glass insulators were then slipped over the wires. A pipe of the same diameter as the cylinder and threaded to it, protected the thermocouple from contact with the quenching liquid. This particular alloy steel specimen was used because it is austenitic at ordinary temperature and has about the same thermal properties as deep-hardening high-carbon steels for the greater part of the quenching operation. Accordingly it exhibits quenching conditions free from the complicating effects of thermal transformations.

The specimen so prepared was heated to the desired temperature, as measured with a portable potentiometer, and then quenched with vigorous stirring in the liquid whose properties were to be examined. A double-hand stop-watch was started when the specimen entered the liquid, and time readings were taken as the galvanometer passed successively lower predetermined e. m. f. set-

<sup>1</sup>Pilling, N. B., and Lynch, T. D., "Cooling Properties of Technical Quenching Liquids," *Transactions of the American Institute of Mining and Metallurgical Engineers*, Vol. 62, page 665, 1920.



tings. To facilitate comparison and interpretation of the results, the ratio of the temperature range was plotted, i. e.,

$$u = \frac{T_t - T_o}{T_i - T_o}$$

where  $u$  is the ratio,  $T_t$  the temperature at any time,  $T_i$  the initial temperature, and  $T_o$  the final temperature. A sample record of observations is given in Table I. Only five or six observations can be taken per minute, so a larger number of points on the curves represent a repetition of the experiment. The repeat experiments checked well and showed ample sensitivity to detect differences in cooling rate of the magnitude involved.

Cooling curves from about 800 degrees Cent. (1470 degrees Fahr.) were obtained for this specimen quenched in water, 50 per cent, 75 per cent and 100 per cent solutions of commercial glycerin in water, a commercial mineral quenching oil, and an emulsion of 16 per cent oil in water. These curves are shown in Fig. 1. Similar curves were obtained for quenching from 100 degrees Cent. (212 degrees Fahr.) in the same media, except the emulsion, as shown in Fig. 2. These curves bring out differences in the characteristics of the liquids when the specimen is at a relatively low temperature. In certain respects the temperature relations are more important at low temperatures than at high temperatures.

#### SIGNIFICANT PROPERTIES OF THE QUENCHING MEDIA

Quenching curves, to be of any significance, must be correlated with the transformations in steel which govern hardening. There are two primary transformations, designated  $Ar'$  and  $Ar''$ . The first mentioned occurs at about 600 degrees Cent. (1112 degrees Fahr.) in carbon steels when the cooling rate is lower than a certain critical value and determines the distribution of hardening, for the product of this change, troostite or sorbite, is relatively soft. The metal untransformed here, persists as austenite to a considerably lower temperature where it changes to martensite, at  $Ar''$ , thereby attaining maximum hardness. Hence the most critical rate of cooling is that just preceding  $Ar'$ , for it determines whether or not martensite will be formed subsequently at any point in the specimen, and so controls the ultimate distribution of hardening.

Below  $Ar'$  the cooling rate is of secondary importance, so far as the final results are concerned, until  $Ar''$  is reached. At this transformation the volume increases 1.5 per cent or more on complete hardening of high-carbon steels. The cooling rate is important at this point, for if the volume changes do not occur simultaneously throughout the whole specimen, internal stresses will result. We are then especially interested in the cooling properties of the baths for specimen temperatures in the neighborhood of  $Ar'$ , say  $u=0.7$  on the ratio scale, and of  $Ar''$ , say  $u=0.2$  on the ratio scale.

From the time it takes for the center to cool to  $u=0.7$  in the several media, Fig. 1, it might be concluded that oil is intermediate in cooling rate between the 50 and 75 per cent glycerin solutions. If, however, we compare the slopes of the curves on this horizontal, we find that the actual cooling rate of oil is between that of undiluted glycerin and its 75 per cent solution. The cooling rates taken from the curves are assembled in Table II

under  $\frac{du}{dt}$ . These results indicate that glycerin-water solutions of high glycerin concentration do not absorb heat from surfaces at a high temperature as well as oil. This effect is transient and disappears before the temperature of  $Ar'$  is reached at the center. Nevertheless, cooling times are not a reliable criterion of the cooling power of liquids.

It is surprising to find that an emulsion of oil in water cools the specimen more slowly than either of the apparent constituents, but only so long as mention of the third constituent, air, is neglected. The oil was emulsified and maintained in that condition by passing air from a high-pressure tank through the mixture. The entrapped air-bubbles evidently facilitated the formation of a vapor blanket around the hot specimen and the viscosity of the emulsion retarded its removal, thereby retarding greatly the cooling of the specimen at high surface temperatures. When the surface of the specimen approached the temperature of boiling water, steam no longer formed and the cooling was found to be intermediate between oil and water, Table II,  $u=0.2$ . The point at which active boiling ceases is shown by a marked break in the cooling curve, Fig. 1. It will be demonstrated in a subsequent

section that this property of such an emulsion is not entirely unfavorable for certain hardening jobs.

The amount of martensite found in a steel quenched in the several media should be roughly proportional to the cooling rates obtained with those media. For this reason, 1-inch diameter cylinders of 1.00 per cent carbon, 1.4 per cent chromium steel

Table I

Observations of temperature at the center of a 1-inch diameter, cylinder of 32 per cent nickel steel during quenching in water

t	M. V. Temp. degrees Cent.		$\frac{T_t - T_o}{T_i - T_o}$
0	31.2	748	1.00
5.3	25.0	598	0.79
9.3	17.0	410	0.53
24.7	5.0	121	0.13
37.7	2.5	61	0.04
55.3	1.5	37	0.01
....	1.2	26	0

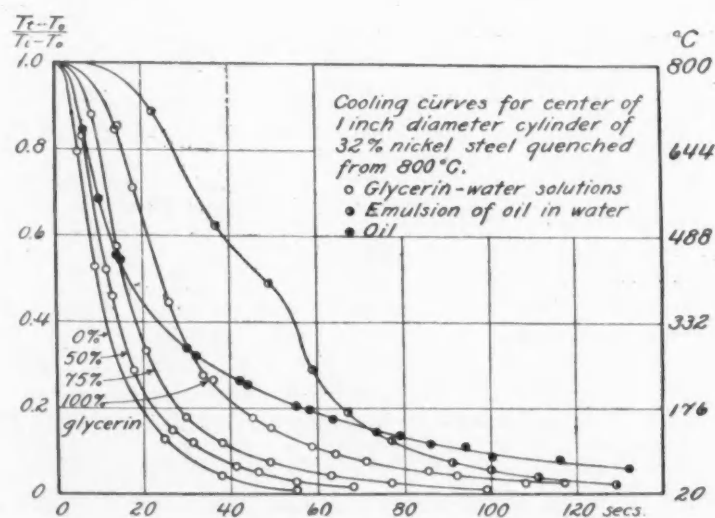


Fig. 1—Quenching Curves for Center of 1-inch Diameter Cylinder of 32 per cent Nickel Steel Quenched from 800 degrees Cent. (1472 degrees Fahr.).

were quenched in the several media and examined for martensite. These cylinders were completely hardened, i. e., entirely martensitic, after quenching in water and in the glycerin-water solutions,

but not hardened in the emulsion. The oil hardened a greater volume of the steel than pure glycerin. These observations check with the order of the cooling rates of the slower cooling media and indicate that the cooling rates as measured are a reliable criterion of the penetration of hardening in steel.

The cooling rates of the glycerin-water solutions vary con-

**Table II**  
**Cooling properties of glycerin-water solutions and oil derived from experimental cooling curves of an austenitic nickel steel cylinder**

Quenching Medium	$\frac{du}{dt}$	$h$	$\frac{u_s}{u_c}$
Quenching temperature 800 degrees Cent. (1472 degrees Fahr.) $a^2 = 0.033$ $u_c = 0.70$ $c = 1.25$ cm.			
Water	0.077	15	0.06
50 per cent glycerin	.063	5	.19
75 " " "	.058	4	.23
100 " " "	.036	1.4	.49
Oil	.044	2.1	.38
Emulsion	.020	0.7	.67
Quenching temperature 800 degrees Cent. $u_c = 0.20$			
Water	0.016	3.6	0.25
50 per cent glycerin	.014	2.6	.33
75 " " "	.012	1.9	.40
100 " " "	.008	1.0	.57
Oil	.004	0.4	.77
Emulsion	.010	1.4	.50
Quenching temperature 100 degrees Cent. $u_c = 0.60$			
Water	0.043	2.7	0.32
50 per cent glycerin	.028	1.3	.52
75 " " "	.022	0.9	.62
100 " " "	.011	0.4	.78
Oil	.009	0.3	.82

tinuously with the composition, but not proportionately. Thus the cooling rate decreases with increasing glycerin concentration much more rapidly at high than at low concentrations. This indicates a close relation between cooling rate and boiling point for the boiling point rises slowly with increasing glycerin concentration when the concentration is low, and rapidly when it is high, Table III. Hence the composition of solutions of high glycerin content must be closely controlled to maintain a constant cooling rate. This can be easily accomplished by hydrometer tests. Table III

gives the relation between density and concentration of glycerin-water solutions.

Another notable characteristic of glycerin and its water solutions is the rapid cooling they produce at low specimen temperatures ( $u_c=0.2$ , Table II) in contrast with oil. Thus a glycerin-water solution giving the same rate as oil at  $u_c=0.7$  will cool over

Table III

Density and Boiling Point of Pure Glycerin-Water Solutions from Thorpe's Dictionary of Applied Chemistry

Weight Per Cent Glycerin	Density 20 Degrees Cent.	Boiling Point Degrees Cent.
100	1.260	290
90	1.234	138
80	1.207	121
70	1.180	114
60	1.153	109
50	1.126	106
40	1.099	104
30	1.072	103
20	1.046	102
10	1.022	101
0	0.998	100

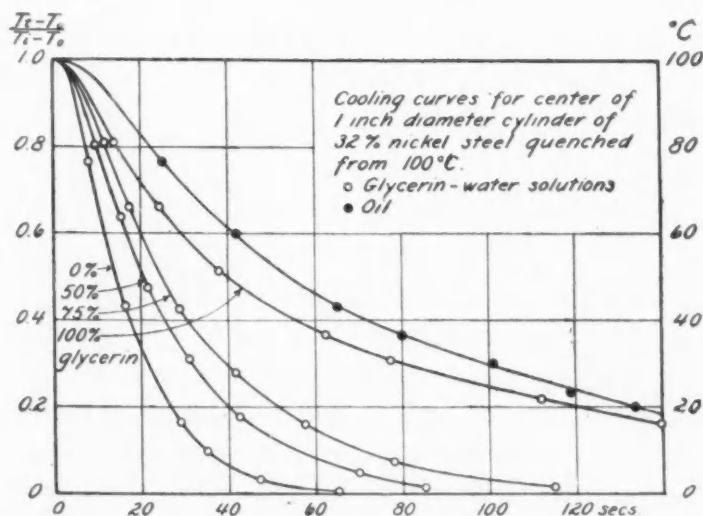


Fig. 2—Quenching Curves for Center of 1-inch Diameter Cylinder of 32 per cent Nickel Steel Quenched from 100 degrees Cent.

twice as fast as oil at  $u_c=0.2$ . In the following section it is shown that the cooling rate through  $A_r''$  has a specific, though small, effect on the constitution of martensite as revealed by hardness tests,

but a more important consideration is its effect on the internal stress. The stress effects, are, however, very complicated and cannot be predicted with confidence. Lacking specifications for the ideal quenching medium, it cannot be stated whether the more

**Table IV**  
**Hardness of deep-hardening steels as quenched in oil and glycerin-water solutions**

Hardening Treatment	Hardness	
	Rockwell (C scale)	Scleroscope (Recording)
<b>A Steel</b>		
820° C. to oil	61.8	89
“ “ “ 75% glycerin	65.3	94
“ “ “ 50% “	67.4	98
“ “ “ water	68.5	100
<b>B Steel</b>		
780° C. to oil	66.2	91
“ “ “ 100% glycerin	66.5	92
“ “ “ 75% “	68.0	95
“ “ “ 50% “	68.4	97
Quenched in oil 20 secs., then in:		
Air	63.9	89
Oil	65.7	92
Water	66.8	94

rapid cooling of glycerin solutions than of oil at low temperatures, is for better or for worse.

The physical characteristics of glycerin are such as to make it a very acceptable quenching medium. It is not chemically active under the conditions proposed and does not give off fumes to an objectionable degree. Being soluble in water it is easily removed from the treated pieces by rinsing in water. Its initial cost is rather high, at present about \$1.10 per gallon for crude glycerin in bulk, but this is offset by the fact that it does not decompose on heating as do oils and that it may be diluted with water. Pure glycerin is hygroscopic and absorbs water up to 50 per cent when exposed to air, but the absorption is not rapid. A beaker of 95 per cent-glycerin decreased in concentration by only 2 per cent



on exposure to air for one month. There is then no obvious physical-chemical feature of the solutions which would prevent their commercial use if justified by their thermal properties.

#### VARIATION OF HARDNESS WITH QUENCHING MEDIA

As noted in the preceding section, the proportion of martensite to the softer constituents of hardening, and hence the mean hardness, increases with the cooling rate. The soft constituents are, however, not tolerated, at least on the surface of hardened steel. Hardness tests are useful for detecting the soft areas, but are of chief interest only when applied to fully hardened steel, i. e., steel cooled throughout at a rate faster than the critical cooling rate. It is generally supposed that the hardness increases by increasing the cooling rate beyond the critical rate, but there is no specific data available on this point. Consequently, a few experiments were made to determine the magnitude of the variation in hardness of martensite with cooling rate. For this purpose specimens 4 inches long by  $1\frac{1}{8}$  inches in diameter were prepared with two parallel faces  $\frac{3}{4}$  inch wide and hardened in the several quenching baths. Two steels of the following compositions were used:

	Carbon per Cent	Manganese per Cent	Chromium per Cent	Tungsten per Cent
A	1.00	0.31	1.37	---
B	0.88	1.12	0.51	0.52

The B steel hardened completely in all the media and the A steel in all except pure glycerin and possibly oil. Any troostite formed in the A steel oil-quenched was, however, so deep as not to affect materially the hardness which was measured on the plane longitudinal faces.

The scleroscope and Rockwell hardness tests were employed, for, having diamond contact points, they gave promise of detecting small differences in extreme hardness. The results are given in Table IV. Both tests showed a definitely higher value following fast cooling than slow, but the difference is greater in the A than in the B steel. This is evidently due to the fact that the variation is conspicuous only when the critical cooling rate is closely approached.

The particular features of the quenching media which govern

this variation of hardness are not entirely evident from the above results. The hardness is obviously a function of the cooling rate; but the cooling rate in what region? In search of an answer to this question, three specimens of the B steel were heated to 780 degrees Cent. (1436 degrees Fahr.) and quenched simultaneously in oil for 20 seconds and withdrawn. One was then cooled to ordinary temperatures in water, one in oil, and one in air. This procedure gave the specimens identical treatments down to a temperature just above  $A_r''$ , so any differences in hardness noted are a result of the cooling through and below  $A_r''$ . A definite difference between extremes of about 5 per cent was observed, Table IV. This variation is of sufficient magnitude to justify the conclusion that the rate of cooling through  $A_r''$  is the major thermal factor governing the hardness of pure martensite. This conclusion is further justified by the fact that the martensite formed during the early stages of  $A_r''$  is at an active tempering temperature, hence the slower the cooling here the greater the tempering and consequent softening.

The difference in hardness between the above extremes of cooling rate through  $A_r''$  is so slight as to suggest the possibility of controlling the stresses developed in deep-hardening steels at  $A_r''$  by withdrawal from the quenching media before  $A_r''$  is reached and cooling thereafter at an appropriate rate. Such procedure would, however, be restricted to the quenching conditions where there is not an excessive temperature difference between center and surface, for it is essential to withdraw before the surface reaches  $A_r''$  and after the center is well past  $A_r'$ . The temperature difference between center and surface which will permit this treatment can be found from simple relations discussed in the next section.

Tool steels are generally used in the tempered condition, so it is of interest to note that the higher hardness incurred by faster cooling is well maintained up to a temperature of 150 degrees Cent. (302 degrees Fahr.), Fig. 3. Above that temperature it is rapidly lost, the advantage practically disappearing above 300 degrees Cent. (572 degrees Fahr.). There are then definite variations in hardness produced by variations in cooling rates above the critical cooling rate which persist on tempering up to 300 degrees Cent. (572 degrees Fahr.). Just what relation these hardness values bear

to the serviceability of a tool steel is an open question, but they do reveal pronounced differences in the heat treatment of fully hardened steels and this is, of itself, a valuable characteristic, for it affords a check on the hardening treatment.

#### EXTENSIONS OF THE COOLING DATA

The cooling rates produced by the several baths have been determined at the center of a 1-inch diameter specimen of one specific composition only. To determine experimentally the cool-

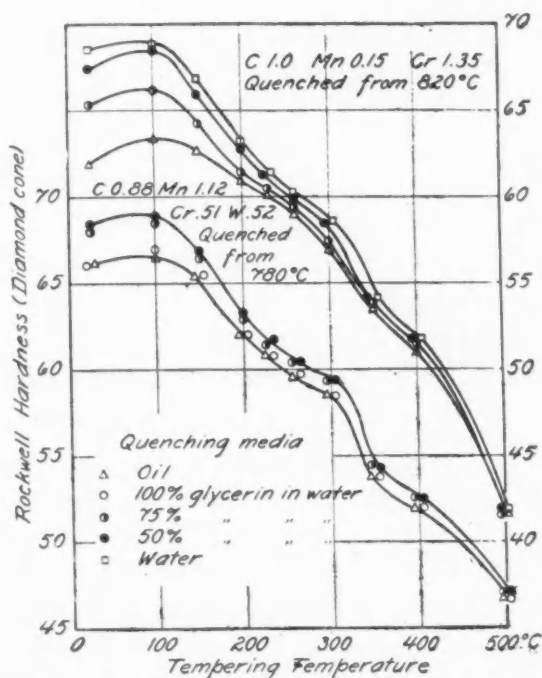


Fig. 3—Effect of Quenching Media and Tempering Temperature on Rockwell Hardness of oil-hardening steels. Right-Hand Scale for Upper Set of Curves, Left-Hand for Lower.

ing rates at this and other points in cylinders of other diameters and compositions would require a prohibitive amount of work. Fortunately much of this information can be acquired by simple calculations. If we assume that the cooling rate is directly proportional to the temperature, i. e., Newton's law of cooling, cooling curves can be constructed with appropriate constants which closely fit experimental curves for cooling from low temperatures. On cooling from high temperatures the correspondence is not very close over the whole range, but is good over short ranges. As we are interested in the temperature relations in the vicinity of the

transformations only, this situation presents no difficulty other than that of selecting an appropriate cooling constant for each range.

Previous considerations have shown the importance of the cooling rate at  $Ar'$  and of the temperature gradients at  $Ar''$  on the outcome of a given quench. It is consequently desirable to determine the effect of the cooling power of the quenching medium and of the size of the specimens on these thermal factors. Such has been done and the results embodied in two curves, one of which gives the cooling rate multiplied by a constant to be evaluated, and the other an expression for the temperature difference between the center and surface, both plotted against the cooling power of the quenching medium multiplied by the radius of a cylinder. The derivation of these general relations is beyond the scope of this paper and will be treated elsewhere, but their significance and application is discussed below.

Assuming Newton's law of cooling, an expression can be derived from the theory of heat conduction, which gives the cooling rates in a section not near the ends of a long cylinder. In this expression:

$$-\frac{c^2}{a^2u} \times \frac{du}{dt} = (ke)^2,$$

$a^2$  is the diffusivity, a constant of the metal alone,  $c$  the radius in centimeters and  $ke$  a function of  $hc$ , where  $h$  is a property of the cooling medium alone which defines cooling power. This expression holds when  $hc$  is large, only after the center has cooled through 0.3 of the temperature range of quenching, i. e., when  $u$  is less than 0.7 at the center. As  $hc$  is decreased, this limit is extended to higher temperatures. Since

$ke$  is a function of  $hc$ , the value of  $-\frac{c^2}{a^2u} \times \frac{du}{dt}$  can be plotted against

$hc$ , as in Fig. 4. This relation shows that the cooling rate is inversely proportional to the square of the radius and directly proportional to the diffusivity for any given value of  $hc$ . Thus if the value of  $h$  is known for a given bath, the ratio of the cooling rates of two cylinders of different diameters multiplied by their

respective radii squared is that of the values of  $\frac{c^2}{a^2u} \times \frac{du}{dt}$  for the respective values of  $hc$ . This ratio, for the same steel, is therefore independent of  $a^2$  and  $u$ .

The above expression also shows that the cooling rate is the same at all points within a cylinder, that is, at a given temperature for times when the expression is valid. The cooling rates at earlier times

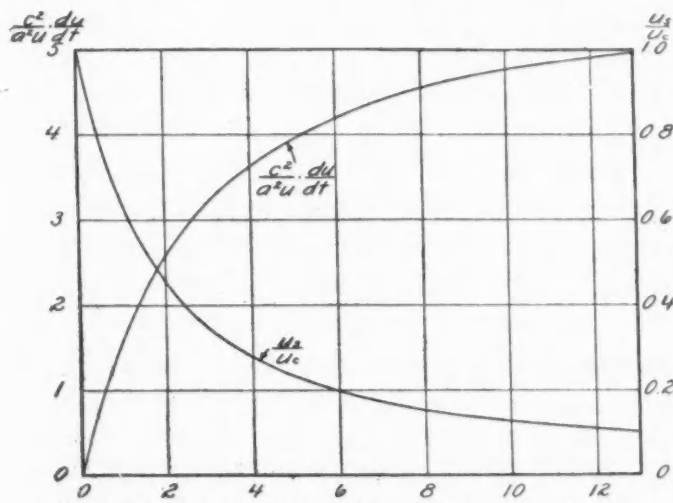


Fig. 4—General Relations Between Cooling Rate at the Center  $\left(\frac{du}{dt}\right)$  and Cooling Power ( $h$ ) and Between the Ratio of Surface to Center Temperature Range  $\left(\frac{u_s}{u_c}\right)$  and Cooling Power for Long Cylinders.  $c$  is the Radius in Centimeters,  $a^2$  a Constant of the Metal and  $u$  the Temperature Expressed as the Ratio of the Temperature Range.

are, of course, faster at the surface than at the center. For those who prefer a graphical illustration, Fig. 5 is included. This figure gives computed cooling curves for the center and surface and several intermediate points within a cylinder 2.5 centimeters in diameter (about 1 inch), using a value of the quenching power  $h$  approximately that of water when the specimen is at a low temperature. When the time is greater than 10 seconds the curves can all be superposed by shifting the time axis as required by the expression for cooling rate. This curve holds not only for the specific constants given, but for any other value of the diffusivity, say  $a_1^2$ , if the times are multiplied by  $\frac{a^2}{a_1^2}$  and for any other radius, say  $c_1$ , if the times are



multiplied by  $\frac{e_1^2}{e^2}$ , so long as  $hc = 3.75$ .

Another important thermal characteristic is the temperature difference between the center and the surface. This may be expressed by the ratio of the surface temperature minus the final temperature to the center temperature minus the final temperature,

i. e., by  $\frac{u_s}{u_c}$  where  $u_s$  is the temperature on the ratio scale at the surface and  $u_c$  the same at the center; both taken at the same time.

This ratio is a function of  $hc$  alone as plotted in Fig. 4, but comes under the previous limitations. Hence the ratio is determined by the bath and the diameter of the piece alone when  $u$  is less than 0.7 at the center. The ratio does not decrease as the temperature falls if  $h$  is constant, so the temperature difference between center and surface must diminish to maintain the ratio constant. With this ratio the temperature of either the center or the surface can be easily found when the other is known, which is to say that the difference can be found for any surface or center temperature and value of  $hc$ . While the ratio is a function of  $hc$ , the temperature gradient, i. e., the temperature difference between two points on a radius divided by the distance between them, is a function of  $h$

alone, at least near the surface. At the surface  $\frac{du}{dr} = -hu_s$ .

Hence the gradient for a given surface temperature does not vary materially with the diameter of the cylinder when quenched in a given medium.

It now remains to evaluate the constants  $a^2$  and  $h$  in order that the above relations may be utilized. If  $a^2$  and the cooling rate at a given specimen temperature are known, the value of  $h$  for the cooling medium used can be taken from Fig. 4. The diffusivity,  $a^2$ , of the 32 per cent nickel steel was found to be about 0.033 in c.g.s. units from experiments to be described at a later date. Taking this value of  $a^2$  and the cooling rates of the several baths at three center temperatures as given in Table II, the value of  $h$  for these baths were found and are given in this table.

The value of  $a^2$  varies with the composition and constitution



of the steel, but the fact that high-carbon steels quenched from above the critical point in water, cool at about the same rate as a high-nickel steel shows that the value for the high-nickel steel is representative of the high-carbon steels. For other steels lower in carbon or alloy content the value will generally be lower. Unfortunately there is very little experimental data in the literature

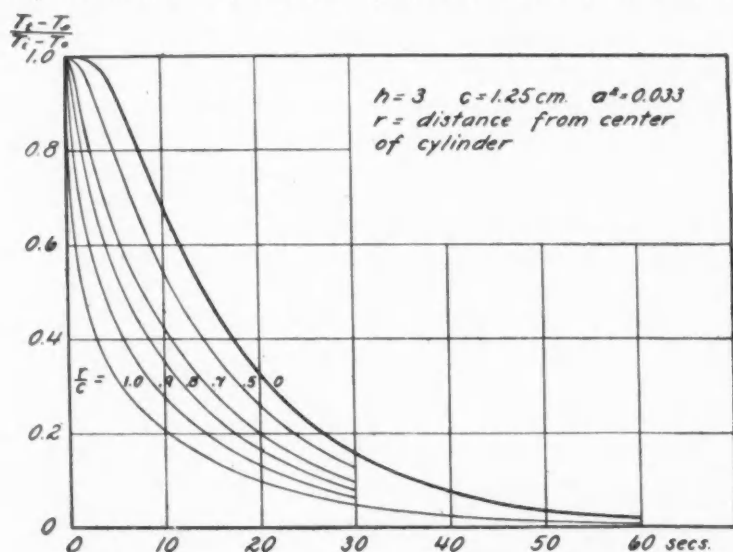


Fig. 5—Computed Cooling Curves for Several Points Within a Cylinder 2.5 cm. Diameter for a Bath of Cooling Power  $h = 3$  and a Steel of Diffusivity  $a^2 = 0.033$ .

on the value of this property or on the thermal conductivity, from which it can be derived, for steels at high temperatures. The value can, however, be estimated from the rate of a long cylinder quenched in a liquid of known cooling power,  $h$ , such as water, by means of the relations plotted in Fig. 4.

Having now approximate values of  $h$  for the several quenching media, the maximum diameter cylinder which will harden completely in each may be readily estimated. From observations of the depth of hardening of a 1.00 per cent carbon steel and of a 1.00 per cent carbon, 1.4 per cent chromium steel, it was estimated that their critical cooling rates are 0.25 and 0.05 respectively in the units employed. These cooling rates were estimated on the basis of  $a^2 = 0.033$ , thereby eliminating error due to the differences between this value and the precise values of  $a^2$  for these steels. Taking  $u=0.7$  at the center, a temperature in the range of  $A_r'$  for normal quenching, the values of  $h$  for several values of  $c$  and for both cooling rates were taken from Fig. 4 and plotted. The value

of  $c$  taken from the resulting curves for a certain value of  $h$  is then that of the maximum radius cylinder, which will harden completely in the medium represented by this value of  $h$ . The

Table V

Computed maximum diameters of cylinders of carbon and chromium steel which will harden to the center in the several quenching media ( $uc = 0.7$ ,  $a^2 = 0.033$ )

Quenching Medium	Maximum cylinder diameter (inches)	
	1% Carbon, 1% Carbon Steel	1.4 % Chromium Steel
Water	0.50	1.22
50% glycerin	.42	1.13
75% "	.39	1.07
100% "	.20	0.75
Oil	.26	0.90
Emulsion	.12	0.47

cylinder diameters given in Table V were so found. These values show to what extent increased penetration of hardening can be expected on substituting glycerin-water solutions for oil.

The values of  $h$ , being proportional to the temperature gradients, show the relative gradients at three different stages of quenching in the several baths, Table II. From  $hc$  and Fig. 4, the temperature difference between center and surface can be easily found. This difference is most important during  $Ar''$ , say when  $u = 0.2$  at the center, for the volume change is greatest there. If the quenching temperature is 800 degrees Cent. (1470 degrees Fahr.) and the final temperature 20 degrees Cent. (68 degrees Fahr.),  $u = 0.2$  corresponds to a center temperature of 176 degrees Cent. (348 degrees Fahr.). For water quenching the

1-inch diameter nickel steel cylinder,  $\frac{u_s}{u_c} = 0.25$  and for oil quench-

ing  $\frac{u_s}{u_c} = 0.77$ . The surface temperature is then  $0.25 (176-20) +$

$20 = 59$  degrees Cent. (138 degrees Fahr.) for water quenching and  $0.77 (176-20) + 20 = 140$  degrees Cent. (284 degrees Fahr.) for oil quenching. The differences between center and surface

are then 117 degrees Cent. (242 degrees Fahr.) and 36 degrees Cent. (96 degrees Fahr.) respectively. Unlike the temperature gradients, these differences increase with the size of the specimen. Thus the same difference as for water quenching would be obtained on oil quenching a cylinder 11.25 centimeters (4.43 inches) in diameter.

These temperature relations show that the emulsion described here might be successfully used in place of oil for quenching large sections of a deep-hardening steel, even though it did not harden the 1-inch diameter cylinder of the A steel and oil did. Hence a steel cylinder of large diameter and sufficiently low critical cooling rate to harden near the surface in the emulsion will harden deeper in it than in oil, for the cooling rate at the center when the center is passing  $Ar'$  will then be governed by the value of  $h$  at the low surface temperature. However, the difference in penetration of hardening between the emulsion and the oil can not be large for reasons developed in the following paragraph.

Caution must be exercised in applying the values of  $h$  given to specific cases for  $h$  changes with the surface temperature while the relations noted above are derived on the assumption that it is constant. The magnitude of the variation is evident from the values of  $h$  for three widely different center temperatures, Table II. As the surface temperature for a given center temperature becomes lower with increasing radius, and vice versa, the derived relations can be applied only when the difference in radius is not large or when an appropriate value of  $h$  is selected. There are, however, extreme cases in which the variations of  $h$  with surface

temperature are negligible. Thus when  $h$  is large,  $\frac{c^2}{a^2u} \times \frac{du}{dt}$  approaches a constant value of 5.78. Hence, if the radius is large, the variation of  $h$  with temperature or with the quenching medium has a small or negligible effect on the cooling rate near the center. The cooling rate is then inversely proportional to the square of the radius. This condition is closely realized on water quenching large diameter cylinders.

The fastest possible cooling is represented by  $\frac{a^2}{a^2u} \times \frac{du}{dt} = 5.78$ .

The 1-inch diameter experimental cylinder quenched in water cools

at a high temperature, only 15 per cent slower than the theoretical maximum. There is then little room for improvement in depth of hardening by the discovery of a more effective cooling medium than water. If such were found it would be of questionable value, for the temperature gradients would be excessively high. It is understood that surface cracks are difficult to avoid even on water quenching ball-bearings. A more rapid quench would only aggravate this phenomenon, while a slower, such as offered by a low concentration glycerin-water solution, should obviate the difficulty without requiring the much slower cooling and lesser hardness conferred by quenching oils.

When the diameter is very small,  $h$  is small, and the temperature difference between center and surface can be neglected in applying values of  $h$ . In this case the cooling rate is given by:

$$\frac{du}{dt} = - \frac{2 a^2 h u}{c}$$

when  $h$  is less than 0.10. The cooling rate is then inversely proportional to the first power of the radius. This relation holds for small wires cooling in air, in which event, the cooling rate may be faster than that at the center of a 1-inch cylinder quenched in water. At the other extreme of cooling rates, approximately represented by water quenching large cylinders, the cooling rate varies inversely as the square of the radius. Obviously, the majority of practical cases come between these extremes, i. e., in the region of

rapidly changing slope of the curve for  $\frac{c^2}{a^2 u} \times \frac{du}{dt}$ , Fig. 4.

It is interesting to note that the glycerin-water solutions approach closer to the theoretical cooling curves which assume  $h$  constant with temperature than the other media. Whether or not this is a desirable property remains to be seen. The chief advantage of these solutions is the greater depth of hardening possible without recourse to water. While it is shown that the source of internal stress effects is in the hardening transformations, no prediction can be made of the best cooling rate in this region for minimum stress. It might seem that the best cooling rate here is the slowest possible. Such cooling would produce no greater soften-

ing than a mild tempering. However, experiments by the author have shown that a moderately slow cooling rate through *Ar*" produces tensional stress at the surface and this is more disastrous than compressional stress. A detailed treatment of this involved subject is evidently required and must be deferred to a later paper.

#### SUMMARY

From observed cooling curves of the center of a 1-inch diameter cylinder of 32 per cent nickel steel taken during quenching in water, in solutions of 50 per cent, 75 per cent and 100 per cent crude glycerin in water, oil, and an emulsion of 16 per cent oil in water, it was found that:

(1) The cooling rate at the center when the center has cooled to 600 degrees Cent. (1112 degrees Fahr.) from 800 degrees Cent. (1472 degrees Fahr.) decreases continuously with the addition of glycerin to water, the decrease being more rapid for high percentages of glycerin than for low.

(2) Undiluted glycerin is slightly slower than oil in this region so its water solutions effectively bridge the gap between oil and water.

(3) At lower center temperatures, say 200 degrees Cent. (392 degrees Fahr.), glycerin and its water solutions give a much more rapid cooling rate than oil, hence it is possible to select a glycerin solution which will harden no deeper than oil and yet cool through the lower temperature range more rapidly.

(4) An emulsion of 16 per cent oil in water agitated with compressed air cooled much slower than oil when the specimen was at high temperatures and considerably faster when at low temperatures.

(5) The unrelated changes in cooling rate with temperature between several of the media show that cooling times are not a reliable criterion of cooling power.

The effect of the quenching medium used is slight, but definitely reflected by the scleroscope and Rockwell hardness of deep-hardening tool steels cooled at rates faster than their critical rate, i. e., completely hardened, those cooled fastest being the hardest. This relation is maintained on moderate tempering.

The cooling rate during the hardening transformation, i. e.,



below 300 degrees Cent. (572 degrees Fahr.) for tool steels, is the principal factor controlling these variations in hardness. It is shown that the major stress effects are generated during this transformation. Since the effect on the hardness is small, it is possible to vary the cooling rate through that transformation over wide limits, if such is necessary to control the internal stress, without material loss of hardness.

While the price of glycerin and its hygroscopic nature is not in its favor as a quenching medium, there are other compensating properties. For example, it does not decompose on heating, has a high boiling point and the composition of its water solutions can be easily maintained by hydrometer tests.

The cooling constants of the baths which define quenching power were evaluated for three center temperatures from the observed cooling rates and properties of the experimental cylinder. From these constants, the maximum diameter cylinders of 1.00 per cent carbon steel and of 1.00 per cent carbon, 1.40 per cent chromium steel which will harden to the center in the several media were estimated. Curves were also prepared from which the cooling rate at the center and the difference between the surface and the center temperature can be estimated for a given bath constant and cylinder radius under certain restrictions. The temperature difference between the center and the surface for a given bath and surface temperature increases with the radius, but the temperature gradient is constant. It is shown from the theoretically derived relations that when either or both the bath constant and the radius are large, the cooling rate at the center of the steel cylinders is inversely proportional to the square of the radius. Water-quenching approaches this limiting case of instantaneous surface cooling so closely that there is no possibility of a real gain in hardness or depth of hardening by a further increase in cooling rate at high temperatures.



# A LABORATORY METHOD FOR THE PREPARATION OF SMALL STEEL BARS DIFFERING ONLY IN CARBON CONTENT AND THE EFFECT OF CHANGES IN CARBIDE CONCENTRATION ON THE SPECIFIC RESISTANCE

BY E. D. CAMPBELL AND G. W. WHITNEY

## Abstract

*By systematic application of the principles involved in carburization by means of carburizing mixtures, decarburization with moist hydrogen, and equilibration in dry hydrogen at 950 degrees Cent. (1742 degrees Fahr.), the authors have prepared four series of steels, comprising 38 compositions, with carbon contents ranging from 0.00 to 1.75 per cent. Two series were prepared from  $\frac{1}{4}$ -inch round bars and two series from bars 6 millimeters (0.24 inches) square.*

*Specific resistance measurements were made on annealed, oil-hardened and water-hardened round bars, and on square bars in both the annealed and oil-hardened conditions. The specific resistances observed for the nearly pure iron-carbon series in the annealed condition, are, it is thought, nearer to those which may be found for strictly pure iron-carbon alloys than any other values so far reported in the literature.*

MORE than a century ago Proust apparently recognized solid solution, for it was in 1806 he stated that white cast iron must be considered as a solidified solution of carbides of iron in iron.<sup>1</sup> Again in 1863, A. Mathiessen<sup>2</sup> considered steel and other alloys as solidified solutions and determined the effect of certain constituents on the specific resistance. It was about fifteen years after Mathiessen's work before metallurgical chemists began to use the solution theory as a means of interpreting the properties

<sup>1</sup>Presidential address by Roberts-Austin in *Journal of the Iron and Steel Institute*, No. 2, 1900.

<sup>2</sup>British Association for the Advancement of Science, page 37, 1863.

A paper to be presented before the Sixth Annual Convention of the Society to be held in Boston, Mass., Sept. 22 to 26, 1924. Of the authors, Prof. Campbell is director of the chemical laboratory, University of Michigan, Ann Arbor, Mich., and G. W. Whitney, chemist with the American Smelting and Refining Company at Leadville, Colorado. Written discussion is invited.

of steel and more than twenty-five years before physical chemists, led by Van't Hoff<sup>3</sup> in 1890, adopted the idea of solid solution and began to develop it along chemical lines.

During the last decade of the 19th Century, the electrolytic dissociation theory of solution, first announced by Arrhenius in 1887, was made the subject of many researches all over the world and very much extended in its application. During the same period the so-called solution theory of steel was being used to interpret the properties of steel, as influenced by variations in composition and concentration of the solutes dissolved in the solvent iron, but no effort was made to develop a general theory of solution which would apply to steel, although it was obvious that the electrolytic dissociation theory could not apply to a solution in which the solvent is a good conductor of electricity.

The solution theory of steel, that is, the assumption that hardened steel is a solution in the strict sense of the word, has formed a background for most of the research work on steel carried on in this laboratory since 1891. During the first ten years of this period, experimental evidence was developed which indicated that the carbides of iron, as well as those of other metals, should, in the light of organic chemistry, be considered as metallo-carbons, that is, derivatives of hydrocarbons in which the hydrogen has been completely replaced by metals. Evidence was also given to show that the molecular constitution of the carbides of iron is much more complex than is indicated by the simple formula  $\text{Fe}_3\text{C}$ , and that the molecular weight of the carbides in steel is influenced by the total carbon concentration and the heat treatment.<sup>4</sup>

It is now generally recognized that carbides are the most important solutes in steel and that the mechanical, electrical, thermal and magnetic properties depend more on the composition and concentration of the carbides in solution than on any other factor. In a recent article, Arnold<sup>5</sup> has summarized the conclusions at which he has arrived as the result of a long, very carefully conducted series of researches extending over a period of about

<sup>3</sup>"Ueber feste Lösungen und Molekulargewichtsbestimmung an festen Körpern." *Zeit. Phys. Chem.*, 5, 322, 1890.

<sup>4</sup>E. D. Campbell, "A Pure Carbide of Iron," *the American Chemical Journal*, Vol 18, pp. 836-847, 1896.

E. D. Campbell, "The Constitution of Steel," *Journal of the Iron and Steel Institute*, Vol XXI, pp. 776-780, 1899.

<sup>5</sup>J. O. Arnold, "The Correlation of the Chemical Constitutions of True Steels with their Micrographic Structures," *Journal of the Iron and Steel Institute*, No. 1, pp. 213-224, 1923.

thirty years. He defines "true steels" as "saturated steels,"—that is to say, steels containing neither structurally free iron nor structurally free metallic carbides. A study of Arnold's work reveals clearly that if a second metallic element is present, it may enter into the constitution of the carbides, thus modifying their solubility; or, it may form a solid solution or mixed crystal with the solvent iron; or, as is not infrequently the case, an equilibrium will be established between that portion of the second element found in the carbides and that occurring in the solvent.

In order to obtain an accurate knowledge of the influence of changes of carbon concentration on the properties of steel, it would seem necessary to have a series of steels in which the carbon alone is the variable constituent. Series of steels differing only in carbon content are not commercially available, although a number of progressive steel manufacturers have always been willing to donate for research work any kind of steel which they regularly produce, and some have made special heats of compositions not suitable for commercial purposes, in order to assist in research work.

The only series of pure iron-carbon alloys so far described in the literature is the one prepared by the Bureau of Standards. A full description of this, together with a series of iron-carbon-manganese prepared at the same time, is found in Scientific Papers #453, #463, and #464 of that Bureau. These two remarkably complete series were prepared in 3-pound lots, by melting electrolytic iron in a vacuum furnace in magnesia crucibles. After fusion of the iron, carbon was added, and when desired, manganese. When carbon is the only element other than iron, it is comparatively simple to make a series such as that made at the Bureau of Standards. However, when the alloy is to contain one or more elements in addition to iron and carbon, it has not been practicable heretofore to produce alloys in which the carbon content can be varied while the ratio of all elements to the solvent iron remains constant. While in the pure iron carbon series the total amount of elements other than iron and carbon did not exceed from 0.01 to 0.03 per cent, when series containing manganese were made, the variation in the per cent of manganese in samples of presumably constant manganese would be as great as 0.40 per cent.

The next most nearly pure series of iron-carbon alloys given in

the literature is one of seventeen steels described by Stablein<sup>6</sup> in 1923. In this series the per cent of carbon varied from 0.05 to 1.65 per cent and the per cent of elements other than iron and carbon (Mn, Si, P, S, Cu, Ni, Cr) varied between 0.28 and 0.46 per cent. The presence of these latter elements necessitated deductions of from 1.77 to 3.77 microhms from the observed specific resistances, in order to give the apparent specific resistance of iron plus carbon alone.

#### OBJECTS

The objects of the present paper are: (1) To give a brief description of a laboratory method by means of which small steel bars, varying only in carbon content, may be prepared. (2) To give the results of specific resistance measurements on some such bars when annealed and when hardened by quenching in oil or in water.

#### MATERIALS USED

In all, four series of bars were prepared, two in the form of  $\frac{1}{4}$ -inch rounds and two in the form of 6-millimeter squares (0.24 inches). One of the  $\frac{1}{4}$ -inch round and one of the 6-millimeter square series was prepared from "armco iron," the second  $\frac{1}{4}$ -inch round series was prepared from tungsten magnet steel, and the second 6-millimeter square series from chrome magnet steel.

Since no adequate supply of electrolytic iron was available, the next best material was "armco iron," manufactured by the American Rolling Mills Company. One lot of this iron, cold drawn in the form of  $\frac{1}{4}$ -inch round rods, was furnished by the Page Steel and Wire Company. These rods were sawed into lengths suitable for work and stamped with a series number, "OA 1." The second lot of "armco iron" was furnished directly from the American Rolling Mills Company in the shape of  $\frac{1}{4}$ -inch thick pieces all cut from an 8-inch wide plate which had been rolled from a billet representing the lower third of an ingot. This iron is designated by the serial number "IN 5."

A lot of  $\frac{1}{4}$ -inch round rods of tungsten magnet steel was furnished for the work by the Halcomb Steel Company. These were cut into suitable lengths, polished until clean and bright, and stamped for identification with the serial number "OH 1."

<sup>6</sup>Fritz Stablein, "Ueber den Einfluss des gebundenen Kohlenstoffs auf den Spezifischen Widerstand des Eisens," *Zeit. Physik*, Vol. 20, pp. 209-228, 1923.

The source of the chrome steels was a stock of  $1\frac{1}{4} \times \frac{3}{8}$  inches bars of chrome magnet steel furnished by the Penn Seaboard Steel Corporation and designated by the serial number "T53." From the chrome steel after annealing, and from the ingot iron plates, small bars were machined out, these bars being 6 millimeters square and of such length that short pieces could be cut off at the ends and leave the finished bars 15 centimeters long. These short pieces were useful in making microscopic examinations, in order to examine for homogeneity of cross-section.

In order to enable one to see the relative atomic concentrations of all the elements in an alloy, Le Chatelier suggested, about thirty years ago, the system of expressing the composition of alloys not only in weight per cents, but in atom per cents. If the weight per cents of an alloy are known, the atom per cents are computed by dividing the weight per cent of each element by its atomic weight and then reducing the values thus obtained to a basis of 100 per cent by dividing each of the individual values by the sum of the whole.

The chemical composition of the four base metals used in preparing the four series is shown in Table I; the weight per cent is given in the upper half and the atom per cents in the lower half.

Table I  
Chemical Composition of Base Metals

Serial No.		C	Mn	P	S	Si	Cr	W	Ni	Cu	Fe
OA1	Wt. %....	.01	.028	.003	.018	trace	....	....	....	.039	99.90
OH1	" "....	.63	.274	.015	.016	.25	.10	5.20	....	....	93.52
IN5	" "....	.015	.024	.005	.023	trace	....	....	....	.042	99.89
T53	" "....	.85	.24	.027	.035	.25	2.23	....	.12	.084	96.16
OA1	Atom %....	.05	.03	.005	.032	...	....	....	....	.03	99.85
OH1	" "....	2.96	.28	.026	.028	.50	.11	1.59	....	....	94.51
IN5	" "....	.07	.02	.009	.040	...	....	....	....	.04	99.82
T53	" "....	3.82	.24	.046	.059	.48	2.31	....	.11	.07	92.86

#### PREPARATION OF SPECIMEN BARS

The three principles involved in the preparation of the specimen bars were: (1) carburization with suitable carburizing mixture under controlled time and temperature; (2) decarburization with moist hydrogen at 950 degrees Cent. (1742 degrees Fahr.);



(3) equilibration in dry hydrogen at 950 degrees Cent. (1742 degrees Fahr.) two steels differing in carbon content.

#### CARBURIZATION

Carburization by heating iron with wood charcoal, animal charcoal, or other organic material, has been practiced for centuries, having formed the basis of the old cementation process for making steel, and is still very extensively practiced in case hardening. In this process the carburization is largely effected through the action of gaseous carbon compounds. The carburizing mixture used in the present work consists of 50 per cent wood charcoal, 25 per cent animal charcoal, and 25 per cent barium carbonate. About 6 kilograms (13.2 pounds) of such a mixture was placed in a porcelain-lined ball mill and ground for two hours in order to insure fineness and homogeneity of the mixture.

From twenty to twenty-two small bars were wired together with soft iron wire, one near each end of the bars, in such a way that the bars were held parallel and about 5 or 6 millimeters apart, thus forming a grid. This grid was then rolled into a cylinder which could be placed in a cylindrical carburizing pot, leaving about a centimeter clearance between the grid and the inside of the pot. This pot was made of high temperature resistant alloy, being 23 centimeters high by 10 centimeters outside diameter, with walls one centimeter thick. It was lined with one layer of sheet iron against the side and bottom, and was provided with a cover made of the same material, having a hole through which a closed porcelain tube may be inserted to the bottom of the pot. This permitted the insertion of a platinum-platinum-rhodium thermocouple, by means of which the temperature was measured. The porcelain tube was long enough to reach to the outside air, thus insuring an oxidizing atmosphere immediately around the couple, although the bead was far enough down to accurately measure the temperature at a point seven or eight centimeters (about 3 inches) from the bottom of the pot. In preparing for carburization, a layer of carburizing mixture was first poured in and the cylindrical grid of bars inserted, care being taken to see that the grid was centered in order to insure uniformity of temperature for all the bars. The porcelain tube was then set in place and the pot filled with car-



burizing mixture, care being taken to see that the mixture was uniformly packed. When the whole was packed, about 500 grams (about 1 pound) of the carburizing mixture being required, the cover was placed on and luted with a finely-ground mixture of four parts silica and one part clay. The pot used for carburizing could be used equally well for slow annealing of steel by merely substituting pure finely ground and ignited alumina for the carburizing mixture in packing.

The furnace used for carburizing had a heating unit consisting of an electrically wound alundum cylinder 15 centimeters (5.9 inches) inside diameter and 30 centimeters high, thus giving a clear heating chamber of these dimensions. This heating unit was thoroughly insulated from radiation losses, and the furnace was so designed as to facilitate repairs when the heating coils burn out. This furnace has been in use with only slight changes for more than ten years, having been found very convenient, as it can be changed over in a few minutes from one for carburizing or annealing into one for heating bars for hardening.

When the pot containing the bars to be carburized had been luted, it was placed in the heating chamber on three small pieces of porcelain, in order to raise it a few millimeters from the bottom, care being taken to center the pot in the cylindrical heating chamber. The space in the heating chamber around and above the pot was then filled by pouring in coke screenings, the upper portion of the coke being mixed with spent carburizer from a previous charge. When the heating chamber had been thus filled, asbestos paper was laid over the coke and followed by two pieces of sheet iron notched to permit the porcelain tube to project through. Another layer of asbestos paper was laid on top of the sheet iron and was held down with a couple of bricks. The thermocouple was then inserted in the slightly projecting tube and the current turned on. With a little experience, the voltage necessary to bring the furnace to a desired temperature can be determined, and the temperature will be reached in about 18 to 20 hours. When the carburization had continued for any desired length of time, usually from one to three days, the switch was opened and the furnace allowed to cool. Some carburizations were carried on as high as 1000 degrees Cent. (1832 degrees Fahr.), and in some cases the current was reduced so as to bring the temperature to

about 840 degrees Cent. (1544 degrees Fahr.) and held at that temperature for one or two days, to allow time for diffusion of carbides without greatly increased carburization before the switch was opened and the furnace allowed to cool to room temperature. Before pulling the switch, the covering of the furnace was slightly raised so that a layer of crushed charcoal or carburizing mixture could be placed on the surface of the partially burned coke. When the temperature of this charcoal had reached that of the furnace, enough reducing gases will have been produced to insure a strong reducing atmosphere during cooling. The switch was then opened and the furnace allowed to cool to room temperature. By these means the bars received what in this paper is termed a "slow anneal," as more than three hours are required for the temperature to fall through the first 200 degrees Cent. (400 degrees Fahr.) and the temperature will be above 100 degrees Cent. after twenty-four hours standing.

Before wiring together the small bars to form a grid, all bars were carefully smoothed, stamped, and numbered for identification, and washed with ether to remove traces of oil, dried and accurately weighed to the nearest milligram. After the carburization had been completed and the furnace cooled to room temperature, the bars were removed. The wires of the grid were then cut, the bars separated and thoroughly washed with water,—rubbing with a cloth until clean,—and then washed with alcohol, followed by ether and dried and weighed to determine gain in weight due to absorption of carbon. At the conclusion of this experiment the bars showed no change in appearance except the change from the white color of ingot iron to the characteristic color of high carbon steel. Analysis of these bars for S and P showed absolutely no gain in either of these elements over that originally present in the bars.

An illustration of carburization may be taken from experiment 122 in which 22 bars of "OA1" were held in the carburizing furnace for three days, the temperature being between 940 and 968 degrees Cent., the greater part of the time being between 950 and 968 degrees Cent. (1742 to 1774 degrees Fahr.). The increases in carbon of these bars as indicated by the percentage gains in weight, are as follows: 1.456, 1.486, 1.474, 1.457, 1.466, 1.481, 1.501, 1.492, 1.524, 1.500, 1.502, 1.487, 1.459, 1.490, 1.484, 1.470, 1.463, 1.477, 1.475, 1.474, 1.472, 1.491. It will be noted that the maximum devia-

tion from the general average was 0.025 per cent below to 0.043 per cent above.

The certificate of the Bureau of Standards, giving the analysis of Electric Steel, Standard Sample No. 51, gives the average carbon as 1.29 per cent. Twelve chemists cooperated. The results of the twelve individual reports, in the order given on the certificate, are as follows: 1.28, 1.28, 1.32, 1.29, 1.28, 1.26, 1.30, 1.30, 1.27, 1.30, (1.30, 1.28; average 1.29 per cent. It will be noted that the

1.29  
maximum deviation of the highest and lowest values reported is 0.03 per cent from the general average.

#### DECARBURIZATION

The principle involved in the preparation of decarburized bars is that first described by one of the authors five years ago in an article on the decarburization of steel with hydrogen.<sup>7</sup> All treatments with hydrogen were carried on in a fused silica reaction tube 92 centimeters (36 inches) long, 40 millimeters (1.5 inches) inside diameter, and with walls 5 millimeters (0.2 inches) thick. The silica reaction tube was supported in the center in a horizontal alundum cylinder 46 centimeters (18 inches) long and about 55 millimeters (2.16 inches) inside diameter and having walls 1 centimeter (0.39 inches) thick. This alundum cylinder was electrically wound as a heating unit, and contained in a sheet iron cylinder 44 centimeters (17.3 inches) long and 26 centimeters (10.24 inches) in diameter. The space between the alundum cylinder and the sheet iron jacket was packed with infusorial earth to reduce heat losses. The small annular space between the silica reaction tube and the alundum heating unit was calked at the ends with asbestos, after inserting a standard platinum-platinum-rhodium thermocouple, the bead of the couple being very close to the center of the furnace.

When it was desired to treat bars with hydrogen, the desired number of bars were stamped, cleaned, and accurately weighed, after which they were formed into a bundle by binding together with pure iron wire and the bars then inserted to the center of the reaction tube. In making up the bundle, care was taken that all bars were separated from one another by at least the diameter of

<sup>7</sup>E. D. Campbell, *Journal of the Iron and Steel Institute*, No. II, p. 407, 1919.

the wire used to bind them together. In order to diminish the amount of heat radiated from the steel bars in the reaction chamber and the rapid loss of heat due to convection currents, the reaction chamber was boxed in by inserting at each end, a flat-bottomed alundum filtering thimble slightly smaller in diameter than the silica tube. Pieces of fine nichrome wire were attached to these thimbles cut to such lengths that when the bottoms of the thimbles were just inside the heated zone, the ends of the nichrome wires were a short distance inside the rubber stoppers, closing the ends of the silica tube. On account of the conduction of heat by the thick-walled silica tube, it was found necessary to keep the ends cool by wrapping with pieces of soft absorbent cloth and allowing the ends of the cloth to dip into beakers of water placed close to the under side of the reaction tube.

When a bundle of bars had been placed in the center of the reaction tube and the filtering thimbles inserted in position, rubber stoppers with the inlet and outlet tubes, were inserted and the joints made vacuum tight by applying alternate layers of beeswax and glue, while the tube was evacuated by means of a water pump. When the stoppers had been made vacuum tight, the stopcock at the outlet end was closed and the tube allowed to fill gradually with hydrogen. When the tube was full, the inlet stopcock was closed and the outlet opened and the tube evacuated and then again filled with hydrogen. This process was repeated three or four times to ensure complete removal of air. When the air had been completely replaced by hydrogen and it was desired to decarburize the bars, the heating current was turned on and the two-way outlet stopcock was turned so that hydrogen could bubble through a Moeneke bottle containing water to indicate the flow of hydrogen. During decarburization the hydrogen was taken from a tank of electrolytic hydrogen, first passed through a porcelain tube containing a roll of copper gauze but not heated, then through a Moeneke bottle containing water, after which it entered the furnace through a two-way stopcock. The temperature of the furnace, which was heated by an alternating current of uniform voltage, was maintained for seven days at from 950 to 960 degrees Cent. (1742 to 1760 degrees Fahr.), the flow of hydrogen being at the rate of from 3 to 4 liters per hour. At the end of seven days, pure dry hydrogen was substituted for the moist by lighting a burner

under the porcelain tube containing the copper gauze and then diverting the gas by means of stopcocks from the Moencke bottle used to saturate the gas with water, to a drying train of  $\text{H}_2\text{SO}_4$ , followed by soda lime, thence to the furnace. Pure, dry hydrogen was allowed to flow until it was judged that all moisture had been swept out, usually from 6 to 10 hours being allowed for this, after which time the outlet stopcock was closed and the furnace cooled.

When it was desired to give the bars what is termed in this paper a "medium anneal," the current was cut and the furnace allowed to cool to room temperature. Under these conditions about one hour was required for a drop of 200 degrees Cent. and a little less than two hours to bring the temperature below the  $\text{Ar}^1$  point. The temperature at the end of seven hours after cutting the current was 260 degrees Cent.

When it was desired to give the bars what is termed in this paper a "very slow anneal" at the close of treatment with hydrogen, the heating current was gradually reduced so that 24 hours were used to lower the temperature from 950 to 750 degrees Cent. (1742 to 1382 degrees Fahr.). During the next day the temperature was lowered from about 750 degrees Cent. to a little below the  $\text{Ar}^1$  point, usually about 640 to 680 degrees Cent. (1184 to 1256 degrees Fahr.), after which the current was cut off and the furnace allowed to cool to room temperature. This "very slow anneal" would naturally produce a more marked spheroidization of the carbides than would be found in the case of "medium annealing."

The bars, when removed from the furnace, should be perfectly free from any signs of oxidation. This will be the case if all moisture had been removed by the dry hydrogen before allowing the furnace to cool. Small amounts of moisture remaining will react with the bars when the furnace is cooling, causing more or less discoloration at the ends of the bars.

The extent of the decarburization may be computed by the loss of weight of the bars, but the actual per cent of carbon remaining should be checked by an analysis by combustion on cuttings from one of the bars.

In the decarburization there is a loss of part of the sulphur originally present in the bars, this loss amounting in many cases to three-fourths of the total sulphur present. Of the elements



usually reported in steel, carbon and sulphur alone are removed by the action of either moist or dry hydrogen.

#### EQUILIBRIUM IN DRY HYDROGEN

The principle involved in this method is that if two solutions, differing in carbon concentration, held in a still atmosphere of pure dry hydrogen at a temperature of about 950 degrees Cent. (1742 degrees Fahr.), that is, well above the  $C_{\alpha}$  point of pure iron, hydrogen will tend to combine with carbon of the dissociated carbides, removing it in the form of hydrocarbons. These compounds coming into contact with the solution of low carbon concentration, will react, the hydrocarbons giving up their carbon with liberation of hydrogen. There are thus two reversible reactions and theoretically there should be an equilibrium established between the carbide concentrations of the two solid solutions and the hydrocarbon concentration in the gas. Since the reaction between gaseous hydrocarbons takes place at the surface of the low carbon solution, and since the solutions are solid, time will be required for the resulting solution to become homogeneous throughout the entire cross-section, as diffusion in such solid solutions must necessarily proceed much more slowly than in liquid solutions. In a previous paper<sup>8</sup> dealing with this iron-iron carbide equilibrium, it was shown that equilibrium was almost established after five days, a cross-section of a six millimeter square bar showing a small area of only about one millimeter in diameter in which the carbides were not quite so uniformly diffused as they were in the remaining 97 per cent of the bar. Holding for seven days insures complete uniformity in distribution of carbides, and in all the work reported in this paper this time was adopted as the one at which bars were held before cooling down to room temperature. In setting up an equilibrium experiment, the desired number of bars of each of the two steels, after cleaning and accurately weighing, were made into a bundle in the same way as was done for decarburization with hydrogen. Care was taken to distribute two sets of bars as symmetrically as practicable in the bundle in such a way as to facilitate uniformity of distribution of the carbides. The bundle of bars was inserted to the center of the reaction chamber of the same furnace as that used for decarburization with moist hydro-

<sup>8</sup>"The Iron-Iron-Carbide Equilibrium in Dry Hydrogen at 950 degrees Cent." *Journal of the Iron and Steel Institute*, No. 11, p. 173, 1923.



gen. The temperature of the furnace was kept constant at 950 to 960 degrees Cent. (1742 to 1760 degrees Fahr.) for seven days, after which the furnace was allowed to cool so that the bars removed from the furnace were annealed as desired.

The loss of carbon of the high carbon bars was computed from the loss in weight of each bar and the increase in carbon of the low carbon bars computed from their percentage increase in weight.

The data obtained from two typical equilibrium experiments show the results that can be expected from the method.

Six original "OA1" bars and thirteen carburized "OA1" bars were made into a bundle as previously described. After the conclusion of the equilibrium experiment, the carbon contents were computed from the changes in weight. The six bars of the original "OA1" were found to contain 1.042, 1.053, 1.061, 1.050, 1.050, 1.045 per cent carbon. The percentages of carbon remaining in the thirteen high carbon bars were computed to be: 0.977, 1.003, 0.981, 0.982, 0.971, 0.982, 0.968, 0.985, 0.974, 0.982, 0.988, 0.990, 0.976. The net loss of carbon computed by deducting the gain of weight of the low carbon from the loss of weight of the high carbon bars was 0.034 per cent of the total weight of the bars. This loss represents between 3 to 4 per cent of the total carbon in the system, hence between 96 and 97 per cent of the carbon was retained by the steel bars but was redistributed among them.

In another equilibrium experiment, eleven bars of original "OA1" and eleven bars of the original "OH1" were made into a bundle and equilibrated by heating in pure dry hydrogen at 950 degrees Cent. (1742 degrees Fahr.) for seven days, after which they were very slowly annealed. At the conclusion of the experiment the carbon contents of the "OA1" bars computed from the change in weights were 0.209, 0.212, 0.205, 0.209, 0.210, 0.206, 0.206, 0.209, 0.208, 0.208, 0.203 per cent. The carbon contents of the "OH1" bars, computed by deducting the per cent losses of weight from the original carbon contents were: 0.379, 0.380, 0.396, 0.400, 0.386, 0.384, 0.386, 0.374, 0.376, 0.383, 0.396. The net loss, computed by deducting the gain in weight of the "OA1" from the loss of weight of the "OH1" bars, was 0.064 per cent of the total weight of the bars.

By utilizing the three reactions,—carburization, decarburization, and equilibration,—enough bars were prepared so that four

sets of derivatives from the original metals were selected. These sets consisted of ten derivatives of "OA1," eleven of "OH1," ten of "IN5" and seven of "T53." One set of each was used in the annealed condition as prepared. One set of each was oil hardened, and one set of "OA1" and "OH1" was water hardened.

#### HEAT TREATMENT

When it was desired to heat bars preparatory to hardening, an alundum cylinder about 7.5 centimeters (2.9 inches) inside diameter and 15 centimeters (5.9 inches) high was placed in the center of the heating chamber of the furnace used for carburizing. On this cylinder was placed a cylinder of nichrome wire gauze, reinforced with heavy nichrome wire and alundum cement. This gauze cylinder was 7.5 centimeters (2.9 inches) inside diameter and 15 centimeters (5.9 inches) high, thus bringing the top of the gauze cylinder even with the top of the furnace. If the annular space between these inner cylinders and the furnace is kept filled with crushed charcoal and the furnace covered as far as practicable to exclude air, bars may be suspended by means of iron wire in the lower portion of the inner heating chamber for any desired length of time without showing any signs of oxidation. The temperature of the bars suspended in the chamber was measured by means of a platinum-platinum-rhodium thermocouple, the bead of which was placed at a point about the vertical center of the suspended bars, and as near the bars as possible. Before placing the bars in the furnace, the furnace was first brought to a temperature a little above that from which it was desired to quench the steel. A number of bars were then inserted and the temperature observed. Usually the bars were allowed to "soak" for 30 to 40 minutes after reaching a temperature very close to that from which they were quenched. The bars could be easily withdrawn from the furnace and immersed in the quenching bath without being exposed to the air for more than one second. When water was used as the quenching medium, the time required for a bar to lose its red color was usually from four-fifths of a second to one second, and the bar reached the water temperature in from five to six seconds. When oil was used, the time required for a bar to lose its red color was increased to from three to four seconds, thus

Table II  
Specific Resistance  
"OA1" Derivatives

No.	Carbon		Annealed		Oil hardened from 922° C. Sp. res.	Water hardened from 914° C. Sp. res.	Increase due to oil quenching	Increase due to water quenching
	Wt. %	Atom %	Rate of Anneal	Spec. res.				
1	.03	.14	v. s.	10.56	10.84	10.94	.28	.38
2	.21	.97	v. s.	11.07	11.15	12.88	.08	1.81
3	.27	1.24	v. s.	11.28	11.38	13.37	.10	2.09
4	.44	2.02	v. s.	11.93	12.03	17.35	.10	5.42
5	.59	2.79	v. s.	12.81	13.34	22.34	.53	9.53
6	.74	3.35	v. s.	13.81	15.19	29.45	1.38	15.64
7	.90	4.06	med.	13.86	21.08	31.48	7.22	17.62
8	1.05	4.71	med.	14.80	25.53	35.73	10.73	20.93
9	1.12	5.01	med.	15.74	25.88	40.23	10.14	24.49
10	1.48	6.53	slow	16.98	31.97	44.63	14.99	27.65

v. s.—very slow

med.—medium

Table III  
Specific Resistance  
"OH1" Derivatives

No.	Carbon		Annealed		Oil hardened from 917° C. Sp. Res.	Water hardened from 922° C. Sp. Res.	Increase due to oil quenching	Increase due to water quenching
	Wt. %	Atom %	Rate as annealed	Spec. Res.				
1	.04	.19	v. s.	21.92	23.05	22.87	1.13	.95
2	.19	.91	v. s.	20.29	22.36	23.05	2.07	2.76
3	.28	1.33	v. s.	19.13	22.02	22.95	2.89	3.82
4	.39	1.85	v. s.	18.85	22.35	22.78	3.50	3.93
5	.48	2.27	v. s.	19.46	22.36	24.26	2.90	4.80
6	.63	2.96	med.	21.09	31.52	33.63	10.43	12.54
7	.85	3.96	v. s.	19.29	21.13	31.22	1.84	11.93
8	1.06	4.90	v. s.	20.81	21.85	36.84	1.04	16.03
9	1.33	6.09	slow	21.05	23.69	43.63	2.64	22.58
10	1.49	6.79	v. s.	22.51	24.26	45.84	1.75	23.33
11	1.75	7.89	slow	23.11	25.70	47.46	2.59	24.35

v. s.—very slow

med.—medium

showing a marked retardation in the rate of cooling by oil as compared to water. Where quenching temperatures are given, the temperatures are those of the bars at the time of withdrawal from the furnace. When microsections of hardened bars were desired, overlength bars were used and sawed almost completely through so that the hardened bar would be 15 centimeters (5.9 inches)

long and the short piece could be easily broken off after hardening. After the bars had been hardened, they were cleaned and polished preparatory to measurement of specific resistance.

#### SPECIFIC RESISTANCE

Measurements of specific resistance were made with the bars immersed in an oil bath which was maintained at 25 degrees Cent. (77 degrees Fahr.) with a variation of less than 0.01 degree Cent.

Table IV  
Specific Resistance  
"IN5" Derivatives

No.	Carbon		Annealed		Oil hardened		Increase due to oil hardening
	Wt. %	Atom %	Rate of anneal	Spec. Res.	Temp. of quenching	Spec. Res.	
1	.00	.00	v. s.	10.48	900° C.	10.63	.15
2	.11	.51	med.	10.93	"	10.99	.06
3	.23	1.06	"	11.35	"	11.58	.23
4	.45	2.06	"	12.12	"	14.46	2.34
5	.60	2.73	"	12.66	"	19.19	6.53
6	.82	3.71	"	13.54	907° C.	24.99	11.45
7	.97	4.36	"	14.00	"	29.19	15.19
8	1.02	4.58	slow	14.86	"	34.04	19.24
9	1.19	5.31	med.	15.52	"	38.81	23.29
10	1.30	5.77	slow	16.16	"	37.37	21.21

The fall in potential over knife edges 10 centimeters (3.9 inches) a part was measured with an L and N precision potentiometer. The millimeter readings of the current through the bar was checked by measuring the fall in potential over a standard 0.001 ohm resistance, in series with the milliammeter, certified by the Bureau of Standards. The cross section of the round bars was obtained by making fifteen measurements of the diameter and the mean taken as the value for computation. The cross section of the square bars was obtained by making 10 measurements in each direction and using the means for computation. All measurements were made with a precision micrometer.

The results of specific resistance measurements on the two series of round bars in the annealed condition and when both oil and water hardened, are given in Tables II and III. The

results obtained on the two series of square bars in the annealed and in the oil hardened condition are shown in Tables IV and V.

**Table V**  
**Specific Resistance**  
**"T53" Derivatives**

No.	Carbon		Annealed		Oil hardened		Increase due to oil hardening
	Wt. %	Atom %	Rate of anneal	Spec. Res.	Temp. of quenching	Spec. Res.	
1	.04	.18	v. s.	29.19	900° C.	30.04	.85
2	.36	1.65	med.	26.21	"	34.12	7.91
3	.50	2.27	med	25.03	"	38.12	13.09
4	.85	3.82	slow	23.79	"	43.81	24.12
5	1.05	4.69	med.	25.99	907° C.	48.91	22.92
6	1.43	6.29	med.	27.03	"	50.31	23.28
7	1.62	7.08	slow	27.72	"	52.09	24.37

At the time the number one "IN5" bars were completely decarburized by treatment for seven days with moist hydrogen, three bars of vacuum-fused electrolytic iron were made part of the bundle under treatment. The specific resistance of the "armco" iron after decarburization was 10.48 microhms, while that of the electrolytic iron was 10.06 microhms. If, therefore, a deduction of 0.4 microhm is made from all the values given for the "OA1" and "IN5" series of annealed bars, the results should be very close to the true values for a strictly pure iron-carbon series in the annealed condition.

#### DISCUSSION

A study of the results given in Tables II, III, IV, and V, tends to confirm certain principles relative to the specific resistance due to carbides in steel. In order that carbides should exert much influence on the specific resistance, it is necessary that they be in solution, their reactivity being dependent on the extent to which their electromagnetic force fields are opened up by the solvent iron.<sup>9</sup> If the carbides are completely precipitated, the size of the carbide particles has very little influence on the specific resistance, neither has grain size nor the presence of amorphous metal due to cold work, although, as is well known, all of these factors exert a marked influence on mechanical properties.<sup>10</sup> Part of the samples

<sup>9</sup>E. D. Campbell, "The Force Field Dissociation Theory of Solution Applied to Some Properties of Steel," *Transactions of the Faraday Society*, Vol. 16, pt. 3, p. 554, 1921.

<sup>10</sup>E. D. Campbell, "The Influence of Heat Treatment on the Thermo-electric Properties and Specific Resistance of Carbon Steels," *Journal of the Iron and Steel Institute*, No. 2, p. 286, 1916.



in the "OA1" and the "OH1" were "very slowly annealed" in order to give the maximum size to the carbide particles. The effect was to retard the rate at which the carbides went into solution on reheating preparatory to hardening, as is shown by the lower specific resistance compared to similar steels which had been "medium annealed." This is quite markedly shown by comparing the values of the "OA1" hypoeutectoid samples with the "IN5" series of similar carbon concentration, and by comparing the increase in specific resistance of the No. 6 sample of the "OH1" which was medium annealed with other samples of the same series which were very slowly annealed, and thus had the carbides spheroidized into comparatively large particles. The effect of the rate of cooling through the critical range, which determines the extent of the association and precipitation of the carbides which were in solution at the quenching temperature, is best illustrated by a comparison of the specific resistances of the "OA1" series in the oil hardened and water hardened conditions. The temperature of the large volume of water used as a quenching bath in this series was 22 degrees Cent. If the temperature of the water had been below 6 or 8 degrees Cent., the increase of a specific resistance due to hardening would have been approximately 10 per cent greater than it was with the quenching bath at 22 degrees Cent. Although it is the concentration and degree of dissociation of the carbides in solution which determines the specific resistance, the complexity of the factors influencing the solution and dissociation are such that no effort has been made to develop a mathematical formula which would express the specific resistance of a given steel in the hardened condition.

The double carbides of chromium and iron, especially in hypoeutectoid metal, are approximately six times as soluble in alpha iron as are the pure carbides of iron.

The measurement of specific resistances in steel is frequently a very valuable method of studying the constitution, but, like the metallographic, magnetic, and X-ray methods of examination, it has distinct limitations which must be recognized. The use of these four methods, as well as some others, will be necessary before we have a satisfactory knowledge of the chemical constitution of steel and the correlation between the chemical constitution and physical properties of this important alloy.



# PROBLEMS OF THE HEAT TREATER AS INFLUENCED BY THE PRE-NATAL HISTORY OF THE MATERIAL

BY P. E. MCKINNEY

## *Abstract*

*Resulting from a study of steel mill melting practices during the World War, the author has observed wide variations in controlling factors in mill practice. He points out that while there has been exhaustive studies made in drafting specifications for high grade carbon and alloy steels in the direction of chemical and physical properties, not enough attention has been given to the methods used in the melting and refining practice.*

*The pre-natal history of the steel, especially pertaining to the melting and refining process, is of much importance to the steel treater who must heat treat these materials after they have been fabricated.*

*Numerous photomicrographs showing typical structures observed in both normal and defective materials, are incorporated in this paper.*

## INTRODUCTION

**O**BSERVATIONS made during the course of the World War, of work performed in various plants which had diverted their activities from successful commercial activities to production of ordnance steel, and the opportunity to draw comparisons between the work of a large number of important plants, showed not only a vast difference in the finished products of the different plants, but also basically different practices throughout the entire process from the melting of the steel to its heat treatment.

These observations tended more than ever to emphasize the great diversity of opinion regarding the controlling factors in manufacturing practices and brought out many cases of diametrically opposite methods of operation in the various plants performing the same work. Probably the greatest variation from a unified standard practice existed between different plants in their melting practice, i. e., that part of the process leading up to the production

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of the solidified ingot. It was this portion of the process which probably benefited to the greatest extent through the pooling of information and the utilization of the experiences of the few firms who had been producing ordnance material during pre-war times.

While great advances have been made in steel production as a whole, it is believed that too little attention is being given by the steel treaters to those treatments which the material receives before it becomes a solidified ingot.

A glance at modern specifications for high grade carbon and alloy steel, shows a rather exhaustive treatment of the subject of composition and physical characteristics as determined by the tensile test, heat treatment, dimensions, tolerances, etc. Usually if reference to the class of raw material is made, it is confined to specifying the process to be used in producing the steel such as, open hearth, electric or crucible processes, with a warning clause as to freedom from injurious defects.

The inference to be drawn from such specifications is that steel is steel, and if the material in question is the product of the process specified and has the specified chemical composition and meets the requirements as to static physical tests, the basic quality of the material is beyond question and any further trouble with this material must therefore be blamed to faulty fabrication or heat treatment, crystallization, fatigue, or some other act of God or man, that has taken place after the material became steel.

#### PRE-NATAL HISTORY IMPORTANT

Development in the art of steel treating has performed wonders in making possible modern engineering developments. The efficiency of practically every modern mechanism is dependent for its functioning on the work of the steel treater. It is believed, however, that at the present time the steel treater is expected to solve all of the problems through heat treatment methods, without sufficient regard or close study of the characteristics of the raw material.

In general the consideration of problems in connection with utilization of modern carbon and alloy steels has been attempted with a pronounced lack of study of the pre-natal history of the material which the steel treater is required to handle. Attempts to solve problems usually centralize in the study of modifications

in forging or rolling practice and heat treatment. These factors, while offering a large measure of success in many cases, the drastic treatments necessary to overcome inherent defects in the basic material are in the nature of a medicine, and will never be as satisfactory as preventative measures based on better melting practices.

The information usually available to the steel treater regarding the character of the raw material, and the basis for most specifications, treats only with the chemical composition of the material and the process by which manufactured, giving no details or specified requirements regarding either degrees of refinement in the melting practice or of the structural characteristics of the material.

#### CHEMICAL COMPOSITION

It is becoming generally recognized that chemical composition in itself is no guide as to the quality of the material, as it is very readily possible to have material produced by the basic open hearth process identical in chemical composition with the highest grade of material made by the crucible process. The classification of material based on the melting process with no further qualification, is also an inadequate method for determining comparative quality of the material. While, ordinarily, steel is classed in order of excellence as follows: electric; acid open hearth; basic open hearth, and Bessemer, it has been proven that by most careful work, there can be produced in a small Bessemer converter, a product superior to the product from an arc electric furnace which has been indifferently operated.

In the manufacture of ordnance steel the necessity for transverse tests often brings in evidence defects which are not detected in steels not subjected to such tests. It is often stated that ordnance steels are in a class by themselves and that such characteristics are not required for other purposes. While it is true that for many unimportant purposes, the use of high quality material would be wasteful, there are many branches of engineering where frequent failures are experienced which might be avoided by closer scrutiny of the class of material used.

A trip of inspection through automobile service stations or to junk dealers who purchase scrap from automobile repair plants

will reveal many broken parts which are not the result of misuse or accident on the part of the driver. Many of us have had the experience of taking a car to the garage for repairs, and being informed by the repair man that a certain part broke because it became crystallized. Investigation of failures in such cases will show nothing in the history of forging, rolling or heat treating, which will solve the mystery. Usually the pre-natal history of the material is either not available or is so indefinite as to defeat further investigation, so that our investigation winds up by blaming it on to dendrites, excess phosphorus, or some cause for which we would never reject the steel before the failure occurs.

Metallographic investigation embodying both microscopic and macroscopic examinations of the material has been very helpful in diagnosing the cause of some of our troubles, and when properly applied is a valuable aid in selection of material and elimination of unsuitable raw stock.

#### SEGREGATION AND INCLUSIONS

Usual methods of comparative degrees of excellence is the presence or absence of gas, segregation of constituents, and inclusion of non-metallic impurities. The latter may occur in several forms and originate from several sources. Defects of this character cannot be eliminated by forging or heat treatment, although it is possible in some cases to greatly improve the quality by careful heat treatment. Mechanical work such as forging and rolling, tend to elongate these inherent defects in the raw material, in the direction in which the steel is given the most work. Physical tests taken at right angles to the direction of mechanical work will show evidence of such inherent defects, through a falling off in the value for ductility, resulting in brittle bend tests, crystalline fractures, laminated structures or spots, and so-called "snow flakes."

An ideal steel from the standpoint of freedom from inherent defects is one in which tests taken at any angle from the forging, will show practically identical physical values. Such a state of perfection in raw materials is not always attained in practice, but it is possible to obtain them under ideal operating conditions. It is well known that the average structural steel having perfectly safe values as determined by the conventional methods of testing,

would show values on transverse tests, in no way comparable to longitudinal tests. In fact, if engineers judged the quality of structural steel by the result of tests taken at right angles to the direction of rolling, a very small percentage of all structural steel produced, would be pronounced satisfactory.

It is not the purpose of this discussion to urge that all steel regardless of the purpose for which it is intended, shall be of the highest quality, but it is the author's purpose to present evidence that chemical composition, the results of commercial physical tests, and a statement as to the process by which the steel is made, does not necessarily furnish a guide as to the quality and usefulness of the material.

#### MELTING PRACTICE

The following factors not ordinarily covered in specifications, but concerning information which is usually not available to the heat treatment man, contributes to determining the basic quality of the material:

- (a) Temperature conditions during melting and refining
- (b) Condition of slag during refining and at the finish
- (c) Method of introducing ferro-alloys and deoxidizers
- (d) Condition and temperature of metal before tapping
- (e) Method and speed of teeming ingots
- (f) Size of ingot used for a given purpose
- (g) Type of ingot mold used
- (h) Temperature of metal entering the ingot
- (i) Shrinkage of the ingot on cooling
- (j) Behavior of the ingot during solidification
- (k) Temperature of stripping ingot

In the average metallurgical classification of materials, the above factors are given scant consideration. The heat treatment man's problem is usually to obtain with a material of given chemical composition, certain prescribed physical values such as longitudinal tensile tests and Brinnel hardness, which are inherent to the material and tend only to prove that the heat treatment was properly performed. In average practice, the nature of the prescribed tests are such as to preclude the detection of defects which may have a marked influence on service ability, especially as it pertains to the ability of the material to withstand prolonged service or unusual stressing.



Many instances have been noted where generally acceptable commercial steels have failed to perform satisfactory service under unusually severe requirements, only to be replaced by material of similar chemical and tensile properties, but produced under very exacting practice, and have been found to function in a perfectly satisfactory manner.

In one instance a chrome-nickel steel shaft was required to withstand a load of approximately 75 per cent of its elastic limit. The stress of the shaft was torsional, involving the instantaneous application of full load at a speed of 1400 revolutions per minute. The best grade of chrome-nickel automotive shafting stock which fully complied with prescribed chemical and physical tests, utterly failed to perform this service. Shafting made from material of similar composition, but produced under the most exacting melting practice, subsequently treated to the same physical properties, was substituted with entirely satisfactory results.

Many similar instances might be recorded where material with questionable melting history, but entirely satisfactory under ordinary commercial specifications has utterly failed when subjected to service where the design made it necessary to apply maximum or unusual stresses.

When it is considered that any method of steel production involves a number of complex chemical and physical reactions, it can readily be seen that variations in practice of melting and handling the molten metal must necessarily have a decided influence on the resultant material.

Regardless of the process used, the manufacture of steel ingots can be divided into several distinct operations as follows:

- (a) Melting operation
- (b) Oxidizing and boiling operation
- (c) Refining and cleaning operation
- (d) Tapping and teeming operation
- (e) Solidification

The chemical reactions involved in steel production can be briefly outlined as follows:

First;—an oxidation process accompanied by boiling, the purpose of which is to burn out the impurities, and to separate the non-metallic impurities from the metal. The product of this reaction is iron alloyed with more or less carbon and non-oxidizable

metals and metalloids, with more or less oxygen dissolved in the melt.

Second;—the arresting of oxidation and the removal of surplus oxygen. This is accomplished through the agency of temperature control and reducing agents such as carbon, manganese, silicon, calcium carbide (in the electric process), aluminum, vanadium, etc. The product of this reaction is an alloy of iron, carbon, manganese, silicon, etc., from which practically all oxygen has been removed.

The addition of alloying metals such as nickel, chromium, etc., do not usually play a part in the major chemical reaction, as they are ordinarily dissolved in the metal at a period during the reactions, which precludes their influence.

The degree to which surplus oxygen has been used before the completion of the oxidation reaction, together with the ultimate degree of refinement accomplished during the reducing reaction, largely determines the quality of the finished product.

Every steel maker recognizes that it is extremely difficult to remove the last trace of oxygen from the steel even with the use of the most violent deoxidizing agents. The theory that traces of oxygen remain, even in apparently perfectly refined steel, is proven by the fact that when such steel is held in a molten state, entirely insulated from contact with atmospheric oxygen, a reduction of the oxidizable ingredients such as manganese and silicon takes place. This reaction is more or less pronounced depending upon the degree of refinement of the steel. Such reactions continue until the metal is solidified, the resultant oxides of slag freezes out in threads and globules between the grains.

The further exposure of the metal to atmospheric oxygen during tapping and pouring into ingots, adds more oxygen and a tendency to accelerate the reaction.

The agitation of the metal during pouring tends to float most of the insoluble oxides, or slag, to the surface of the metal, but as the solidifying metal becomes more viscous, further elimination of impurities is arrested, leaving these insoluble bodies suspended in the metal. From this it will be seen that the speed of solidification plays a most important part, and that indifferent practice in this operation may even defeat all of the good work performed in preceding operations.

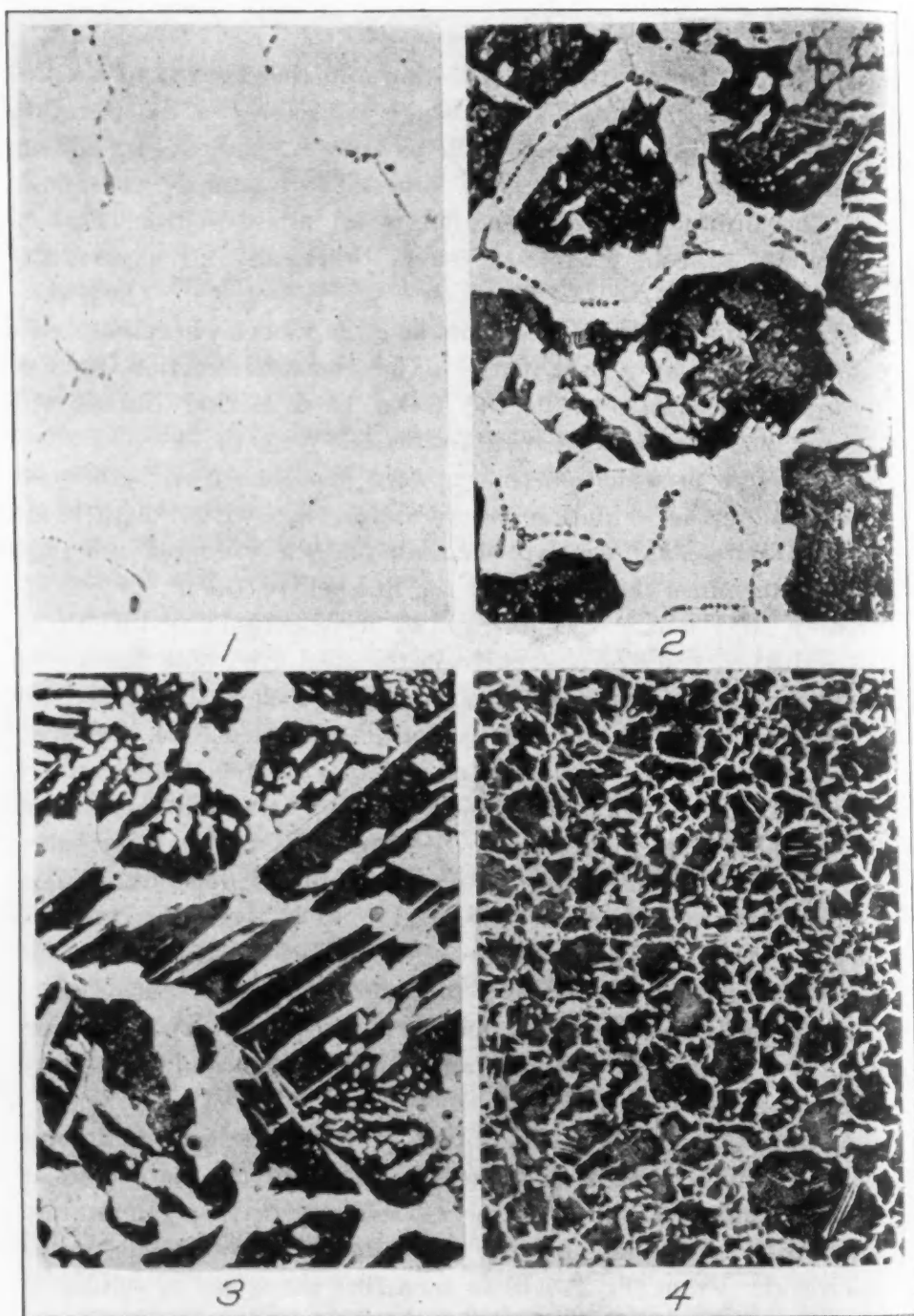


Fig. 1—Structure of Large Ingot Wherein Oxides Have Been Expelled During Solidification. Unetched.  $\times 100$ . Fig. 2—Same as Fig. 1. Etched.  $\times 100$ . Fig. 3—Structure of a Heavy Nickel Steel Ingot Practically Free from Inclusions.  $\times 100$ . Fig. 4—Same as Fig. 3 after Forging and Annealing.  $\times 100$ .

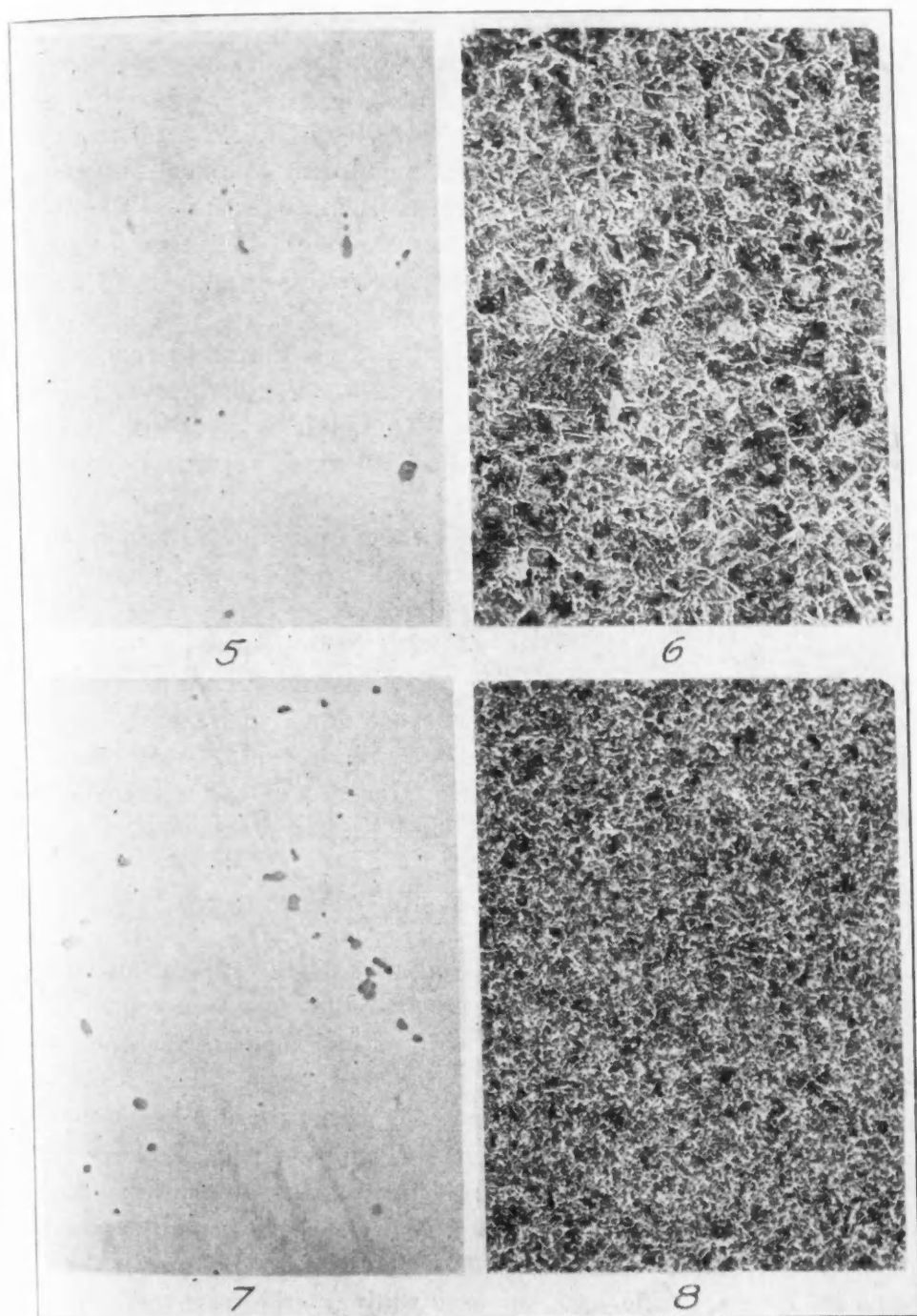


Fig. 5—Structure of Heat Treated Forging Reasonably Free from Inclusions. Unetched. x100. Fig. 6—Same as Fig. 5. Etched. x100. Fig. 7—Structure of Heat Treated Forging Made from a Heavy Ingot Wherein a Considerable Expulsion of Inclusions Had Taken Place. x100. Fig. 8—Same as Fig. 7. Etched. x100.

Since it is known that the last trace of oxygen cannot be removed from the steel and that the reaction between the oxygen, silicon, and manganese continue until the steel has been entirely solidified, the problem seems to resolve itself into the following:

First:—removal of the greatest amount of chemical and physical impurities by the most careful refining practice, involving proper control of temperatures, condition of slag, time for completion of the reactions and the proper selection and use of deoxidizing agents.

Second:—prevention of reaction between the small remnant of oxygen in the steel and the deoxidizing metals, during the process of solidification, by proper control of pouring temperature, and the use of ingot molds which will cause the most rapid solidification of the molten metal.

While these rules hold true in the case of all high quality steels, they are particularly pertinent in the cases where high quality steel must be produced in ingots of large cross section, inasmuch as the solidification of such heavy masses of metal is necessarily slow, even under the most favorable conditions. The resultant inclusions of oxides or slags from such slowly cooled ingots are found in the finished forging as ghost lines, streaks, sand spots, etc., and appear in the fracture of test specimens as laminations, spots, "snow flakes" and similar defects.

#### MICROSTRUCTURES OF STEELS

Photomicrographs in Figs. 1 and 2 show the typical structure of a large ingot in which expulsion of oxides has occurred during solidification. Fig. 1 shows a network of inclusions in the unetched specimen.

Photomicrograph in Fig. 3 shows the structure of a heavy nickel steel ingot practically free from inclusions. Fig. 4 shows the structure of the same material after forging and annealing. Figs. 5 and 6 show typical structures of a heat treated forging reasonably free from inclusions. In this type of material good physical values are readily obtainable both on longitudinal and transverse specimens without any trick heat treatments.

Photomicrographs in Figs. 7 and 8 show typical structures of a forging made from a heavy ingot in which a considerable expulsion



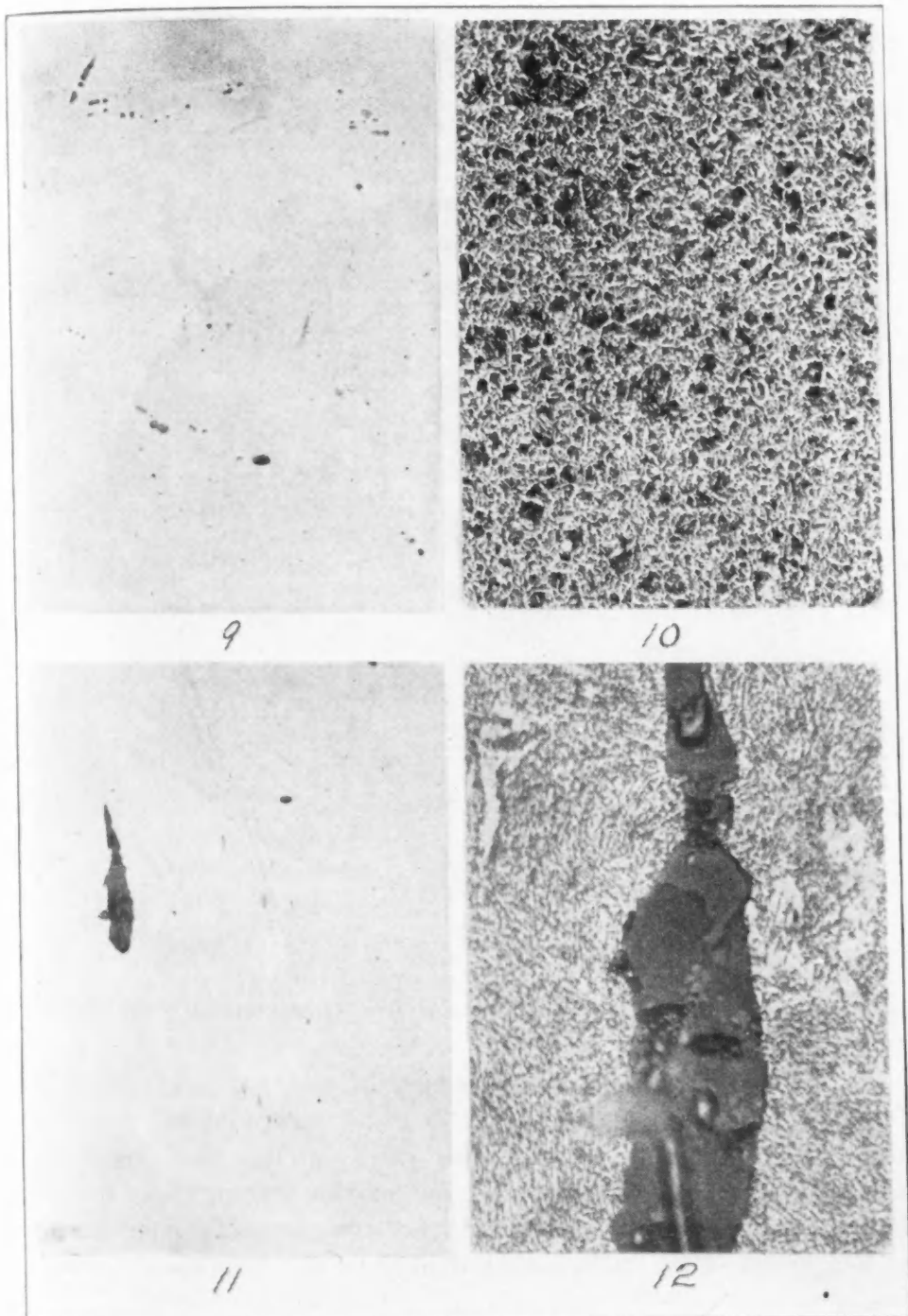


Fig. 9—Structure of Steel Taken from an Ingot Which was on the Border Line of Acceptability from the Standpoint of Inclusions. Unetched. x100. Fig. 10—Same as Fig. 9. Etched. x100. Fig. 11—Structure of a Forging Fairly Free from Inclusions. This Piece Showed a Sand Spot or Split. Unetched. x100. Fig. 12—Same as Fig. 11. Etched. x500. It Will Be Noted that the Inclusion Has not Affected the Surrounding Metal.

of inclusions had taken place during solidification, as is shown in unetched specimen (Fig. 7). The structure resulting from heat treatment shown in the etched specimen (Fig. 8) is perfect, but it was impossible to get satisfactory transverse tests. The elonga-

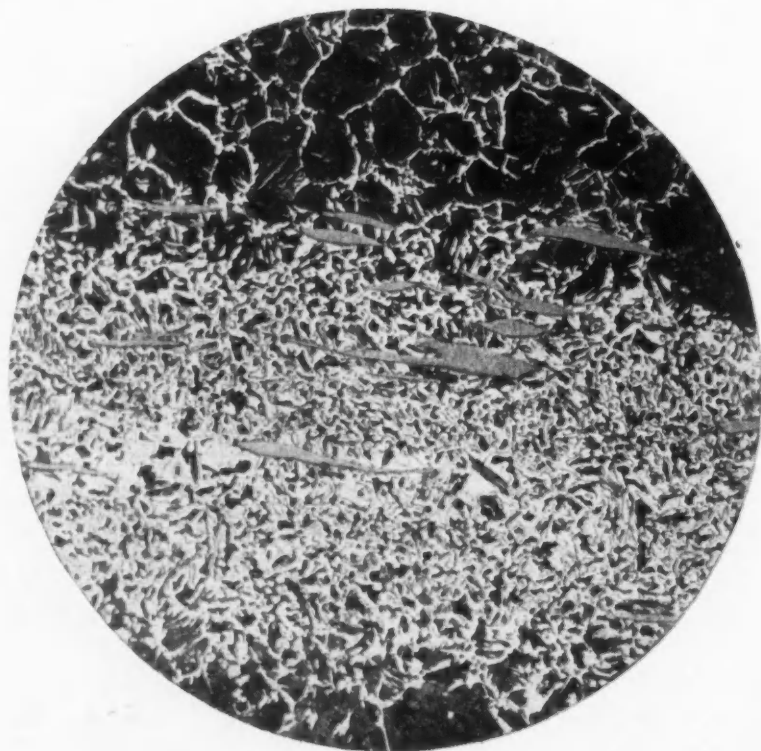


Fig. 13—Photomicrograph Showing the Structure of the Well-Known "Ghost Line." Etched.  $\times 100$ .

tion was deficient and the fractured test specimen showed numerous spots.

Figs. 9 and 10 show the structure of material taken from an ingot which was on the border line of acceptability from the standpoint of inclusions. In this case, careless heat treatment would have resulted in the rejection of the forging. By careful normalizing and grain refinement, the structure was so broken up as to surround the inclusions and prevent the formation of cleavage planes, usually resulting in the falling off in ductility.

The photomicrograph in Fig. 13 shows the structure of the well-known "ghost line" or streak, characteristic of heavy forgings. This indicates a condition in the ingot, far from satisfac-

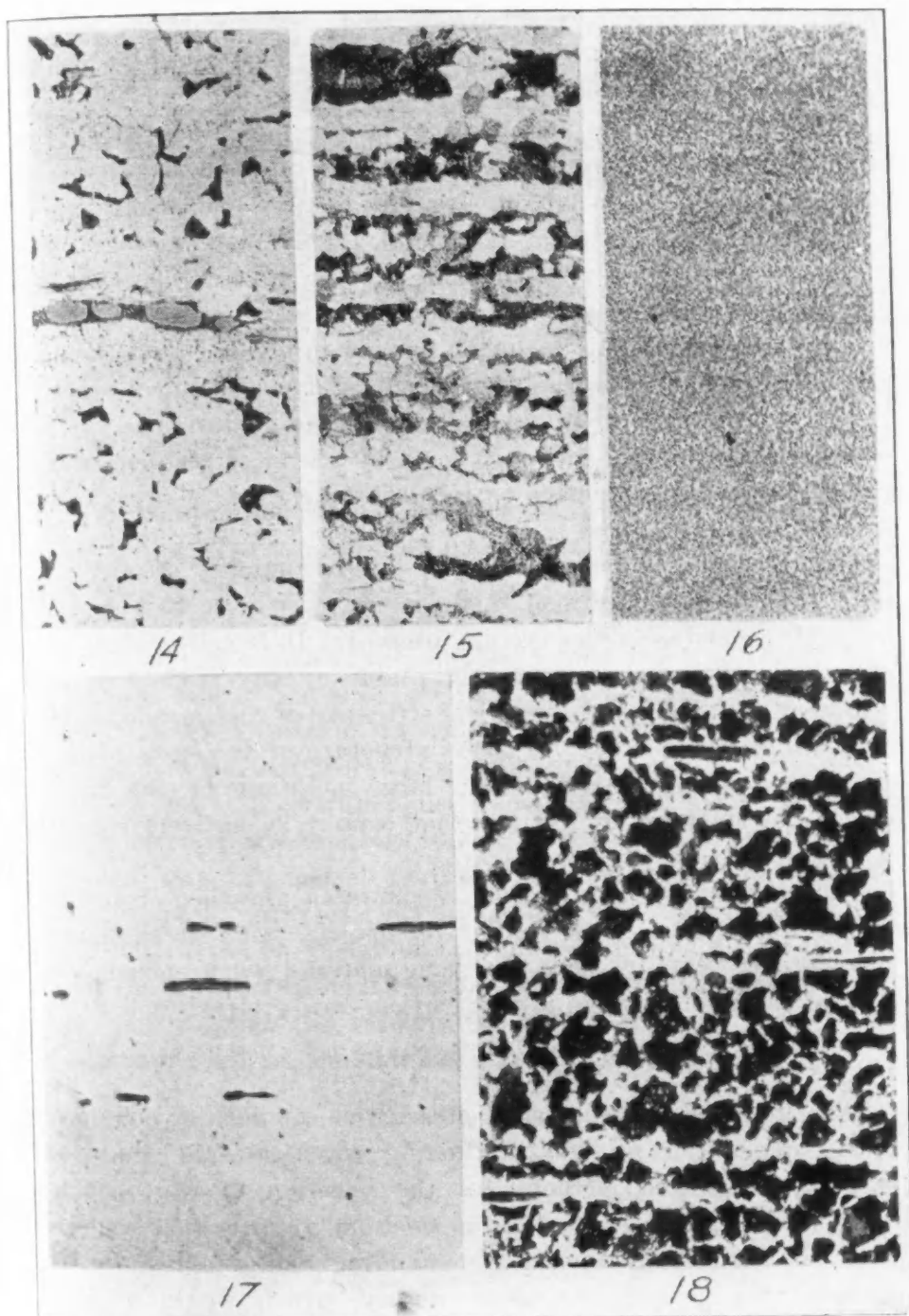


Fig. 14—Structure of an Inferior Quality Engraving Plate. Etched.  $\times 100$ . Fig. 15—Structure of a High Grade Engraving Plate as Rolled. Etched.  $\times 100$ . Fig. 16—Same as Fig. 15, Annealed and Quenched.  $\times 100$ . Fig. 17—Structure of Unetched Stratum of Average Quality Bar Stock.  $\times 100$ . Fig. 18—Same as Fig. 17. Etched.  $\times 100$ . The Effect of Inclusions on Grain Distribution is Apparent.  $\times 100$ .

tory. The reaction between oxides and deoxidizers has been so violent as to affect the surrounding metal. This condition cannot be materially improved by heat treatment.

Fig. 11 shows the structure of a forging fairly free from inclusions resulting from reaction during solidification, but containing physical inclusions of slag due to improper separation of non-metallic material from the metal. This photomicrograph is representative of one type of sand spot or split. Fig. 12 shows the same area etched and magnified 500 times. It will be noted that the material in this inclusion has not influenced the surrounding metal as in the case of slag resulting from chemical reaction in the "ghost line" (Fig. 13). This type of inclusion is far less harmful than the inclusion produced by chemical reaction and is serious only when extensive or in clusters, causing a breaking up of the continuity of the metal.

Fig. 14 shows the structure of an inferior quality of engraving plate. While the analysis of this material show it to be acceptable material, excessive inclusions are present. It is self-evident that such material cannot be made acceptable by any method of heat treatment. Fig. 15 shows a typical structure of high grade engraving plate as rolled. Fig. 16 shows structure of the same material as annealed and quenched. While large inclusions of slag are not shown, the striation in the material cannot be entirely removed by heat treatment.

The photomicrograph in Fig. 17 shows an unetched stratum of average quality bar stock similar to material used in automotive construction. Fig. 18 shows the same material when etched. The effect of inclusions on grain distribution can be clearly noted.

#### CONCLUSION

Since it is evident that steel of a given composition may vary greatly depending on the production practice used, and that generally recognized methods for the selection of raw material are insufficient for classification of steels, it appears that the steel treater is entirely justified in demanding the establishment of standards for determining basic quality, which would afford a proper method of classification of material for various purposes. This may be accomplished by:

First;—the classification of material based upon the character

of service for which it is intended, without regard to composition.

Second;—the recognition of approved methods and the establishment of recommended practices for the production of ingot material along the same lines as the established recommended practice for heat treatment of fabricated material.

Third;—the development of methods for testing material, to supplement present methods, which will detect inherent defects in the material. Among others, the following tests are suggested:

(a) deep etching for macroscopic examination of longitudinal and transverse sections of billet or bar stock.

(b) examination of longitudinal and transverse fractured sections of quenched billets or bar stock, for detection of irregularity in grain.

(c) examination of the surface of bar stock for splits or irregularities after the specimen has been upset by cold pressing to at least  $\frac{2}{3}$  of its original length.

Specifications embodying such additional tests could not be enforced at the present time, but data collected from observation on various lots of material would in a comparatively short time furnish the information necessary to establish additional test methods as a part of working specifications.

While it would be ridiculous to contend that such high standards should be made to apply to material required for unimportant purposes, such as concrete reinforcement rods, floor plates, etc., it appears equally preposterous to assume that all classes of steel regardless of the character of the service for which it is intended should be considered on the same basis regarding quality standards, and without the recognition of the necessity for exacting requirements where demanded by the service involved.



## SURFACE STRUCTURE VERSUS INNER STRUCTURE OF METALS

BY V. N. KRIVOBOK AND O. E. ROMIG

### *Abstract*

*This paper discusses the structures which appear on the surface of cast metals and their relation to the inner crystalline organization of the metal. In many instances a "cellular" or "foam cell" appearance has been observed, and evidence is shown that this structure is a surface phenomenon. An explanation is offered of the observed facts involving surface tension and eddy current effects in the molten metal. A larger polyhedral structure was also studied in which these polyhedrons appeared to be representative of the true crystal architecture of the metal. Reference is made to dendritic forms left in relief by the solidifying metal and their relation to the observed cellules.*

*It is shown that the variety of structures appearing on the surface of cast metals is great and may lead to erroneous conclusions regarding the grain size of the metal if care is not exercised in the examination of the specimen, since some of the observed markings are only surface phenomena.*

### INTRODUCTION

IN the preparation of specimens of metals and metallic alloys for metallographic examination, it often happens that very vivid and beautiful structures appear on the surface previous to any etching treatment. These structures may result from two causes, first, the solidification of a metal or an alloy from the molten state, and second, the annealing at high temperatures of a metal which has a smooth surface. In view of the facts, it may be queried whether or not the structure, as often revealed on the unetched surface of cast metal, represents the true internal crystalline structure of the metal?

In this paper, the authors have confined themselves to a discussion of the first condition, i. e., the solidification of a metal or of an alloy from the molten state.

A paper by V. N. Krivobok and O. E. Romig containing a discussion of some of the work presented by the authors in partial fulfilment of the requirements for the degrees of S. D. and A. M. respectively at Harvard University, Cambridge. The investigation was conducted in the laboratory of Dr. Albert Sauveur and under his direction.

## SOLIDIFICATION OF METAL

This type of structure is especially noticeable on the surface of those metals or alloys which do not readily oxidize, or it may also appear on any alloy which has been melted and allowed to solidify in an inert atmosphere or in a vacuum. The authors have studied the surface structures of zinc, tin, and lead melted in air, and of iron alloys melted in a vacuum, for the purpose of ascertaining what relation these structures have to the crystalline structure of the metal as revealed by photomicrography.

In many instances, three types of structures have been observed on the surface of cast specimens. These types are, first, cellular structures which have been noted and discussed by many writers, second, dendritic structures, which stand in relief, and are the true structures of either pure metals or alloys forming solid solutions,<sup>1</sup> and third, large polygonal networks, representing, it is believed, the boundaries of the primary crystallites.

At present the most widely accepted theory of the mechanism of the solidification of metals from the molten mass is the so-called "nuclear" theory advanced by Tammann.<sup>2</sup> This theory is too widely known to be discussed in this paper at any length.<sup>3</sup> Suffice it to say that in the formation of any primary dendritic growth the crystallization is thought to start from a "nucleus" and proceed in all directions until an obstruction, either in the form of another growth, or the walls of the mold, is met. Other older and now discarded theories of the formation of crystals are Quincke's "foam cell" hypothesis, and the formation of grains by convection currents which are prevalent in cooling liquids. These two latter theories, although proven groundless by other investigators as pertaining to the formation of metal crystals, can be applied, it is believed with some success, to the formation of the surface structures.

## CELLULAR STRUCTURES

The cellular structure as shown in Fig. 1 has great similarity to the well known conception of the "foam cells." This structure

<sup>1</sup>This type of structure is due to the formation of primary axes. The spaces between axial branches are later filled in.

<sup>2</sup>"Kristallisieren und Schmelzen" and "Lehrbuch der Metallographie."

<sup>3</sup>A very clear and brief description can be found in "*Principles of Metallography*" by S. L. Hoyt, published by McGraw-Hill Company.

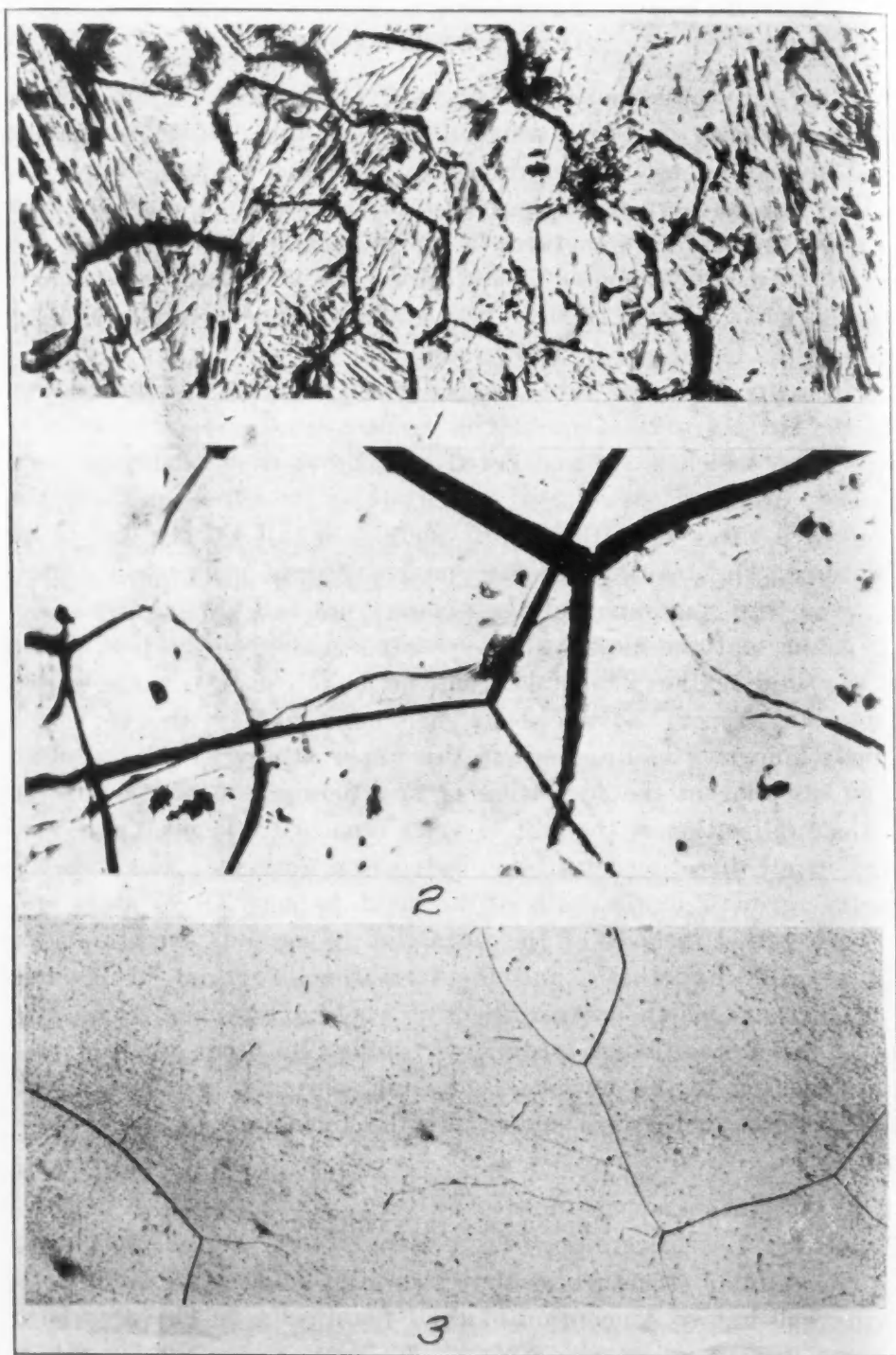


Fig. 1—Surface Structure of Low-carbon Steel Melted in a Vacuum. Unpolished, Unetched.  $\times 100$ . Fig. 2—Surface Structure of Electrolytic Iron Melted in a Vacuum. Unpolished, Unetched.  $\times 65$ . Fig. 3—Same Sample as Fig. 2. Polished and Etched with  $\text{HNO}_3$ .  $\times 65$ .

was obtained on the surface of iron or of an iron carbon alloy melted in a vacuum. More frequently, however, a structure was obtained similar to that of the "foam cells" and reproduced in Fig. 2. It can be seen that there are, strictly speaking, two structures plainly visible. The coarser network consists of large, almost perfect, five or six-sided polyhedrons, with straight outlines adjoining each other in such a way that the sides of the three, (polyhedrons) form angles of 120 degrees. Fig. 3 shows these lines, and under the microscope they are seen to stand in relief, requiring neither polishing nor etching to cause their appearance. Besides this large structure, quite visible with the naked eye (if the light is oblique), another and visibly independent structure of a smaller size, but having the "cellular" appearance is observed. This second network, in general, is outlined by much heavier lines, which, however, in places are of the same or smaller thickness than the outlines of the large structure. It was at first thought that the large polygonal markings on the top of the ingots were the remnants of the original gamma iron structure and that what is called "cellular" structure was the product of the recrystallization of the gamma iron into alpha iron. Both of these structures are rendered visible due to (1) the volatilization of metal at the grain boundaries and (2) to a slight buckling of the surface as a result of the volume change accompanying the transformation. These two conceptions are the modern explanation of similar phenomena. When, however, almost identical structures were observed on the surface of nonferrous metals, and after additional information was derived from the work of others, notably Cartaud,<sup>4</sup> it was suspected that this "cellular" structure was only a surface phenomenon.

The same sample after slight polishing and etching revealed the structure as shown in Fig. 3. In order to arrive at more conclusive results it was decided to examine the same spot before and after the polishing, accompanied by etching.

To accomplish this, an area was selected and marked (Fig. 1). This photograph shows the surface of the casting, unpolished and unetched. Fig. 4 shows the same area after the surface was removed by slight grinding and polishing, and then etched with nitric acid in alcohol. No relation between the surface structure

<sup>4</sup>Cartaud, *Revue de Metallurgie*, Vol. 4, page 819.

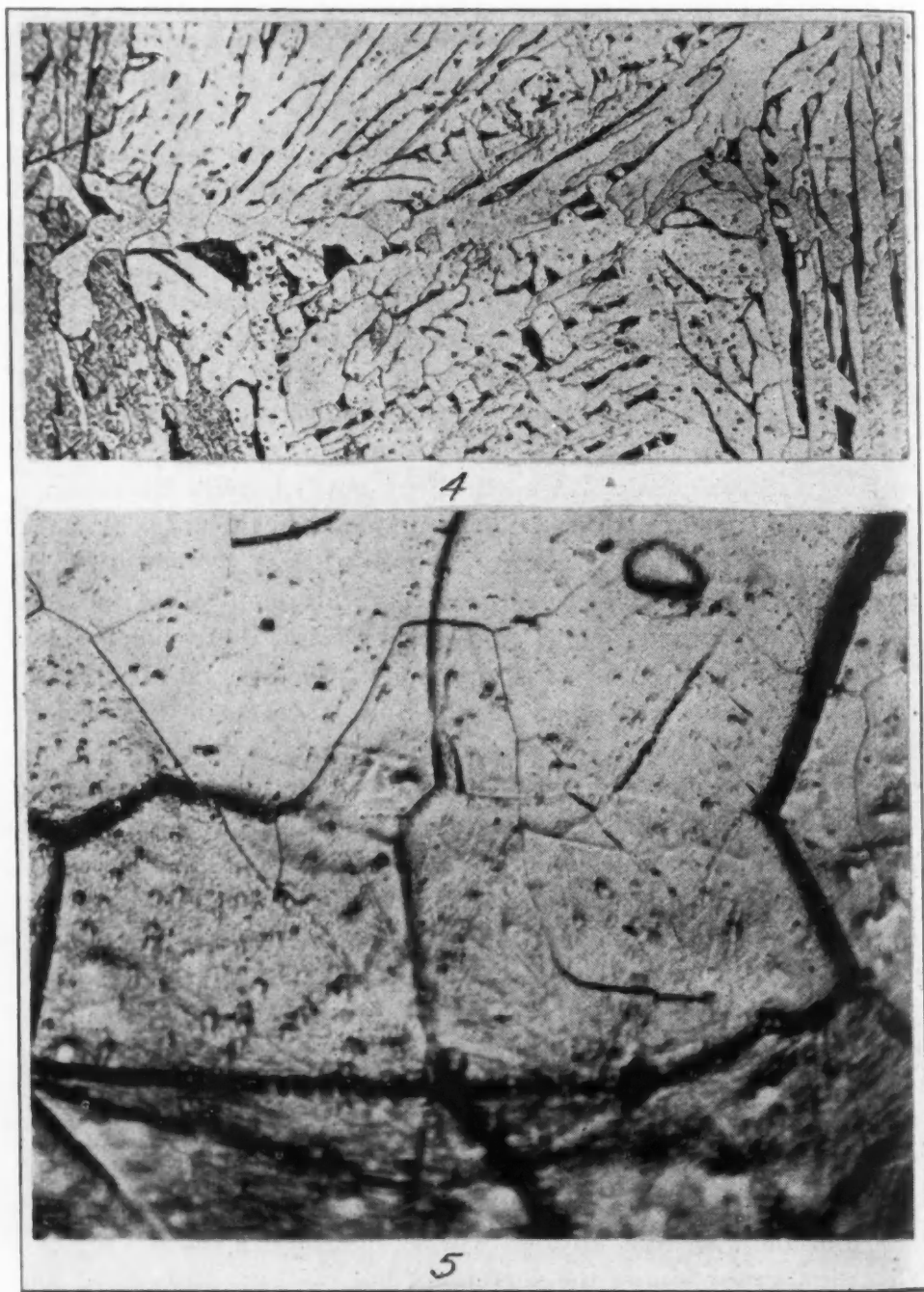


Fig. 4—Same Spot as in Fig. 1. Very Slightly Polished and Etched with  $\text{HNO}_3$ .  $\times 100$ .  
Fig. 5—Surface of Electrolytic Iron Melted in a Vacuum. Unpolished Part of Sample is at the Bottom of the Photograph; Polished and Etched ( $\text{HNO}_3$ ) at the Top.  $\times 65$ .



and the true structure as revealed by etching can be observed. To further substantiate this conclusion the convex surface of one of the iron ingots was levelled out in such a way that part of it was left in the original condition and part polished. The polished part was etched with nitric acid and the original structure protected by a layer of paraffin. Fig. 5 shows the results obtained. The part of the photomicrograph at the top displays the true structure of the metal which is perhaps 1/100 inch below the surface of the ingot. Thin outlines of the ferrite grains are plainly seen. The part of the same figure to the bottom represents the untreated surface of the ingot. Heavy black lines give the idea of the surface structure. Both structures are quite visible and it is conclusively seen that they bear no relation to one another. The composition of this melt was carbon 0.06 per cent and phosphorus 0.09 per cent.

The logical conclusion at which the writers arrived was that the structure which is termed "cellular" was only "skin deep" and is not representative of the true inner structure of the metal in question. The formation of such a structure can, theoretically, be attributed to the globular tendency resulting from surface tension phenomena and to convection currents which are quite probably set up in the cooling liquid.

#### LARGE POLYGONAL NETWORK STRUCTURES

The other type of surface structure described as "large polyhedrons with straight outlines" can be explained, it is believed, by the formation of primary or gamma iron crystallites. It is quite true that in those metals or alloys which undergo recrystallization due to allotropic transformation, the original or primary dendritic growth would be different from the final structure resulting from passing through the critical range. Within the body of alloys of this type, the outlines of the dendritic grains are in most cases rendered invisible, with the exception of course, of those that can be revealed by dendritic segregation. But it does not follow that the outlines of the dendritic growths on the surface of these iron ingots are also obliterated by recrystallization. The development of the large polyhedral network as shown in the photograph in one plane, (plane of the picture) probably resulted from the meet-

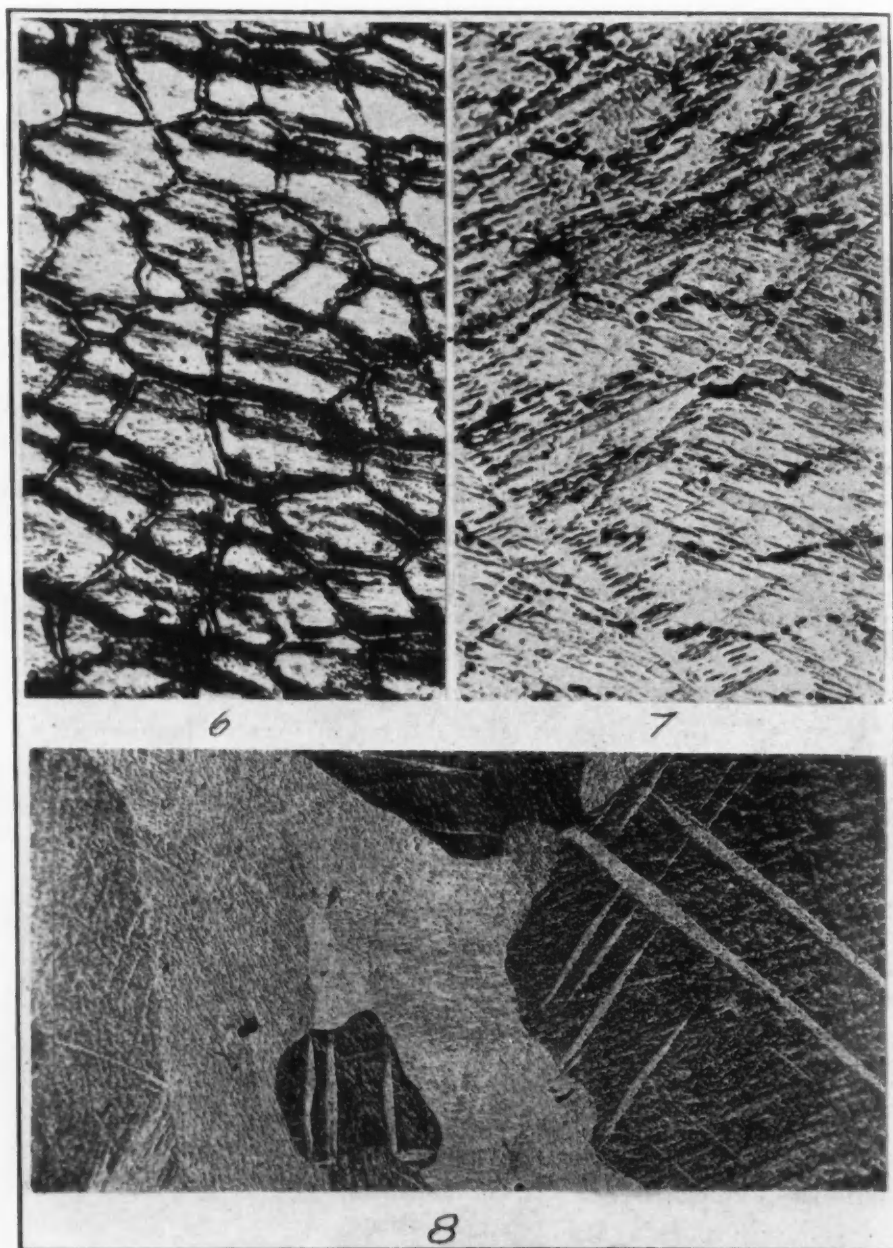


Fig. 6—Unetched Surface of a Bar of Zinc Drawn from Melt in Cooling Stream of Hydrogen Gas.  $\times 100$ . Fig. 7—Same Specimen as Fig. 6 But Polished Slightly and Etched with  $\text{HNO}_3$  and  $\text{CrO}_3$ .  $\times 100$ . Fig. 8—Same Specimen as Fig. 6 Further Beneath the Surface than Fig. 7. Etched with  $\text{HNO}_3$  and  $\text{CrO}_3$ .  $\times 25$ .

ing of the two primary crystallites during their primary crystallization. The outer faces of these crystallites are not necessarily lodged in the same plane, but may form a surface pattern which is

not obliterated by the subsequent transition through the critical range. It can be easily conceived that the visibility of the crystal outlines is rendered possible not only because of the complete absence of surface oxidation, but also on account of melting in a vacuum, which excluded the interference of atmospheric pressure with the development of the crystals.

#### STUDY OF ZINC, LEAD AND TIN STRUCTURES

Zinc, lead, and tin likewise show similar structures on their surfaces, especially if solidified rather quickly. Cartaud shows the development of cellular structures in metals cast on an inclined glass plate. Osmond in writing of Cartaud's work speaks of the surface film as "amorphous" material. Fig. 6 shows the surface of a bar of zinc made by drawing from the melt in a cooling stream of hydrogen. This surface was unetched and is quite representative of the surface of the entire bar.

Fig. 7 shows a section from the same specimen ground down slightly and polished and etched with a mixture of nitric and chromic acids. The remnants of the cellular structure remain, but the crossing of the zinc sutures over these network outlines, plainly indicate that they do not represent the inner structure of the metal. The cellular outline was revealed due to a thin coating of zinc oxide surrounding each globule. Fig. 8 shows a photomicrograph of the same specimen ground down until all evidence of cellular structure had disappeared and only the characteristic structure of cast zinc was revealed. Therefore, it can be safely concluded that here again the cellular structure is only a surface phenomenon.

Fig. 9 shows an area on the surface of a zinc slab poured out on a smooth surface and allowed to solidify. This unetched surface reveals both dendritic crystallites and cellules. The writers believe that the dendritic form represents an area on the surface where the crystalline forces of the metal have been predominant, and that the globular areas represent the superiority of the liquid tendencies of the molten metal. Fig. 10 shows the surface of cast zinc etched with nitric and chromic acids, but without grinding or polishing. On this surface is seen neither a well developed dendritic structure nor a pronounced cellular one. This, there-

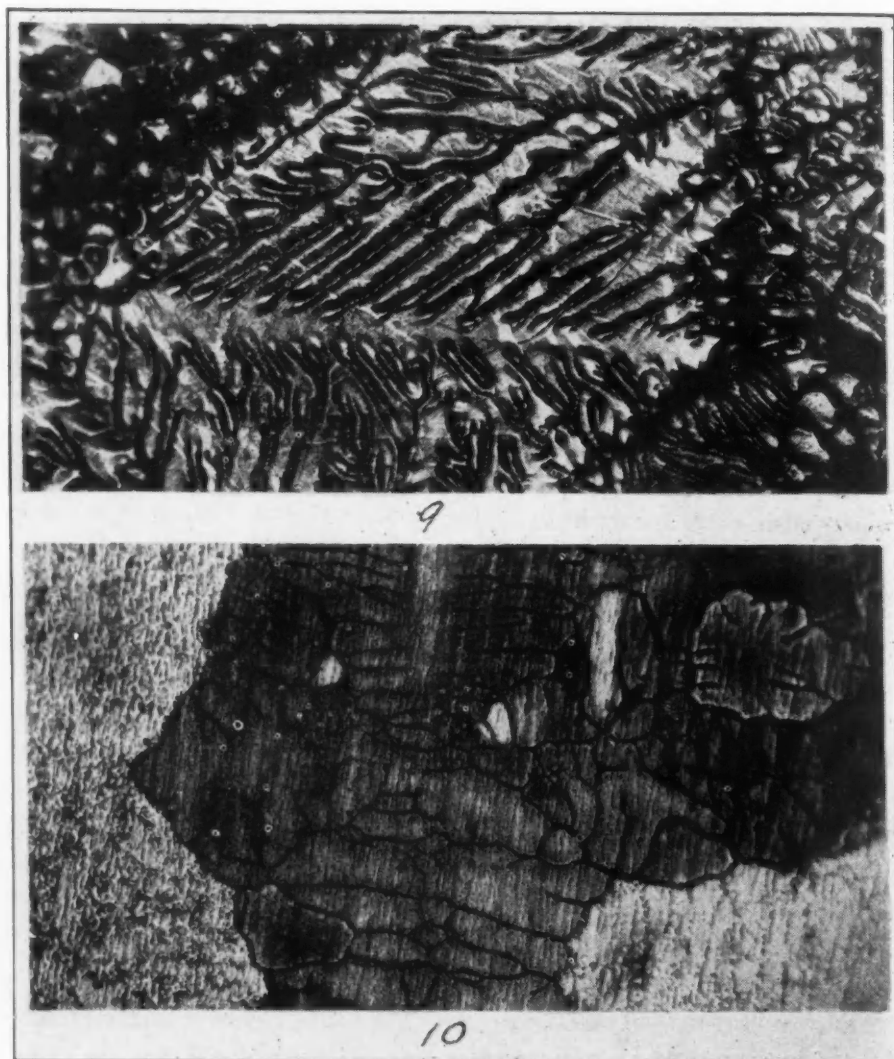


Fig. 9—Unetched Surface of Cast Zinc, Showing both Dendritic and Cellular Structure.  $\times 25$ . Fig. 10—Surface of Cast Zinc Etched with  $\text{HNO}_3$  and  $\text{CrO}_3$  but Not Polished.  $\times 25$ .

fore, has been an area where neither of the two contending forces were paramount. Before etching, the entire surface in Fig. 10 was of a light color. The etching served to disclose the identity of the real crystallites by darkening some crystals more than others. Fig. 11 shows an unetched area on the cast surface of pure lead, which also shows very plainly the cellular structure predominating. Fig. 12 is also an unetched surface of cast lead but not so globular in tendency.

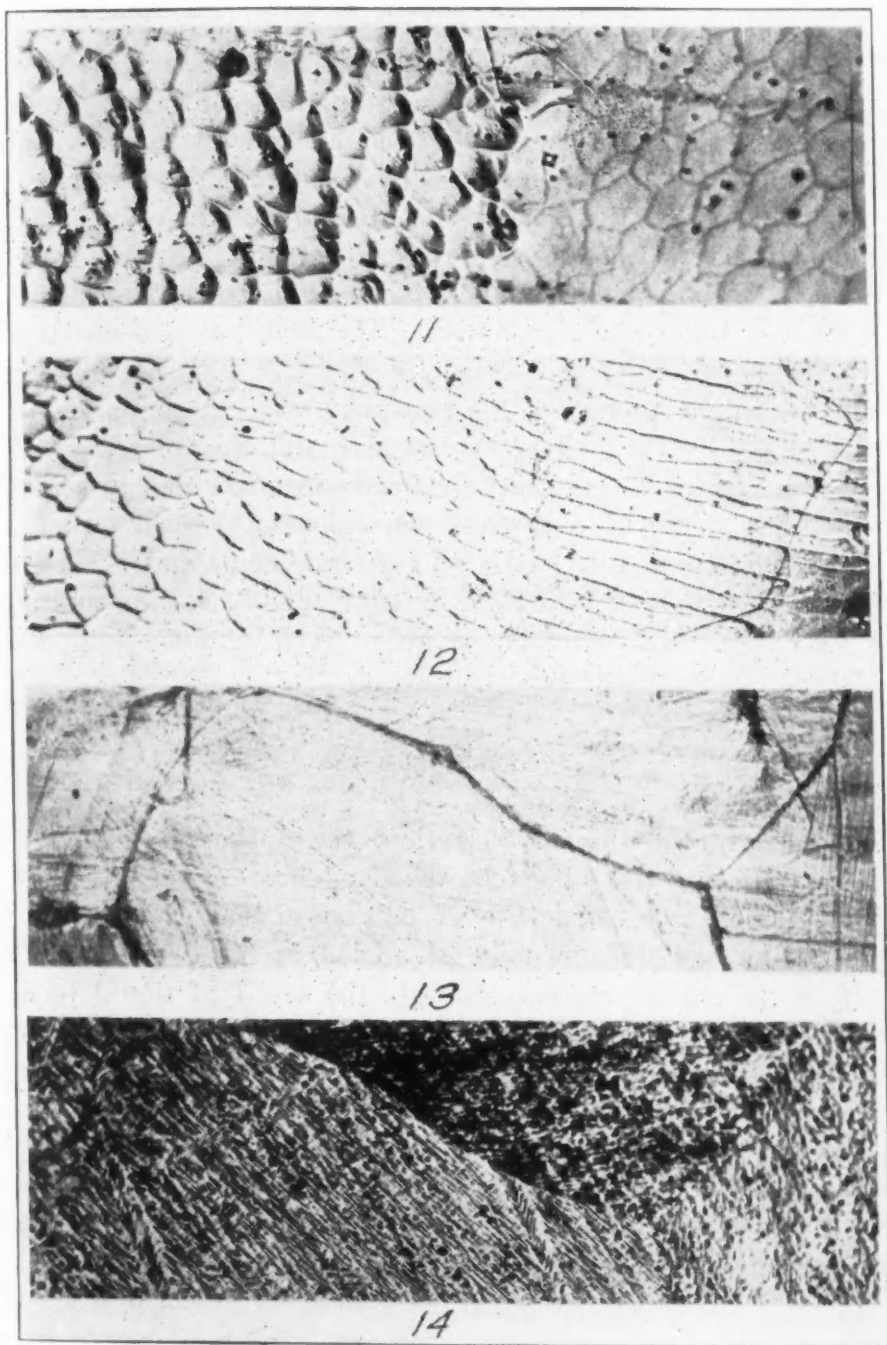


Fig. 11—Unetched Surface of Cast Lead. Cellular Structure.  $\times 100$ . Fig. 12—Unetched Surface of Cast Lead.  $\times 100$ . Fig. 13—Surface of Pure Cast Zinc. Unetched. Polygonal Structure.  $\times 38$ . Fig. 14—Same Spot as Shown in Fig. 13 but Ground Down, Polished and Etched with  $\text{HNO}_3$  and  $\text{CrO}_3$ .  $\times 38$ .



## APPLICATION OF FOAM CELL HYPOTHESIS

In applying the foam cell hypothesis to these structures it would seem that Fig. 11 shows a structure conforming to this hypothesis. Fig. 12 is best explained by convection currents, as its structure is not as globular as it is lamellar in appearance. It is also evident that the lamellar structure is not the only structure evident in Fig. 12. A second larger network may be observed crossing the lines of the lamellæ indiscriminately. It is believed that this is analogous to the five or six-sided polygonal structure previously mentioned and shown in Fig. 2. This network, it is believed, is the boundary of the primary grain. A similar network was observed on the surface of cast zinc and is shown in Fig. 13, unetched. In order to definitely determine that this large grain was not the result of a surface phenomenon, the same area was marked and etched with nitric and chromic acids and is shown in Fig. 14. The writers were able by subsequent grinding and etching to follow this particular grain until it almost disappeared, becoming smaller with each treatment.

## CONCLUSIONS

As a result of this investigation, the authors conclude that surface structures should not be relied upon to give a true indication of the internal structure of cast specimens. Without confirmation by etching, one may be misled in his deduction, inasmuch as such structures may be only the result of liquid tendencies in the solidifying metal. The surface structure may be the true structure of the metal but when such is the case the characteristic outlines are not foam-like in texture.

The writers desire to express their sincere appreciation of the interest taken in their work by Dr. Albert Sauveur, and to extend their thanks to E. L. Reed, Carnegie Research Scholar, for permission to reproduce Figs. 1 and 4.

# SYSTEM AS APPLIED TO THE CONTROL OF FURNACE TEMPERATURES AND HEAT TREATMENT OF AUTOMOBILE TRUCK PARTS

BY JAMES SORENSON

## *Abstract*

*The author of this paper reviews in a general way the necessity of applying an adequate control system in the inspection of raw material for automobile truck parts and their subsequent heat treatment. He discusses briefly a control system for the identification and accurate heat treatment of parts in process. He points out the necessity of laboratory control both in the receiving of material and the inspection of the final product.*

WE ARE all acquainted with the gruelling service an automobile truck receives in the field. Especially is this true where automobile trucks are used for road building. Naturally such heavy-duty service-demands call for the strongest material that is obtainable, in order that the total weight of the truck may be kept at a minimum and also that the heavily stressed parts may stand up under the most severe service conditions.

The object of this paper is to describe in a brief manner the methods of control used in a modern heat treating department handling parts such as are used in the manufacture of a modern light-weight heavy-duty automobile truck.

## STANDARDS AND SPECIFICATIONS

The development and maintenance of standards of practice are very essential. These standards or specifications, as we may call them, should be adopted only after a complete study of the individual parts and of the materials from which they are made, and the proper heat treatment to be applied. After a suitable material and heat treatment has been selected, it is quite essential that it should be strictly adhered to at all times.

A paper by James Sorenson, metallurgical engineer, Four Wheel Drive Auto Company, Clintonville, Wis.

### CHECKING OF RAW MATERIALS

As each shipment of raw material is received from the steel mill or source of supply, samples are taken for chemical analysis for the purpose of determining whether or not the material in question has the proper chemical composition. If the material is found to be within the limits of the specification, the end of each bar is painted with a color which indicates, according to the standard color scheme chart, the particular specification or chemical composition covering that type of material. By classifying and identifying each bar or piece of material in this way, there is little danger of similar shaped or sized pieces of various compositions becoming mixed. With this method of marking the steel, it would be an easy matter for a total stranger to go out into the steel warehouse and select any type of material he may choose. With the proper discipline and personnel, it is not at all difficult to maintain such a system.

### MACHINING OF PARTS

Some truck parts are heat treated before machining and some are heat treated in the semimachine finished condition. The condition of the material and its state of process consequently, will have considerable bearing in prescribing the method of handling during the heat treating operations. It is, however, not the author's intention to deal with individual parts in this paper, but rather the general methods of control used in the heat treatment of automobile truck parts.

### DETERMINATION OF CRITICAL POINTS ESSENTIAL

Before the parts in question are heat treated, a decalescent or heating curve, should be run on a test piece for the purpose of determining the transformation points in the material. It is very important that the transformation apparatus used for this purpose be checked to the same standards as those that are used in the heat treating operations. The use of the information obtained from these curves is one of the surest ways to obtain accurate results, but even this method is not absolutely proof against error. The transformation apparatus may be inaccurate or there may have been an error in marking the test piece, all

of which would cause trouble. The apparatus, therefore, should be frequently checked and test specimens carefully marked and checked. These transformation curves should be run on every heat of steel as received from the mill, as these curves will be of material assistance in determining the correct quenching temperatures to be used in the heat treating of the parts.

#### CHARGING OF THE FURNACE

When parts are ready for heat treatment, great care should be exercised so as not to overload the furnaces or bring them up to the required temperature too rapidly, as either of these methods is almost certain to produce nonuniform results. This is one phase where good judgment is as much, if not more essential, than any other step of the process. Uniformity of all factors is imperative and if not maintained, is sure to cause trouble. The writer has experienced more trouble due to excessive furnace charges than any other one factor, consequently too much thought and care cannot be given to the study and determination of the proper size of the charge to be used for each furnace. The methods used to placing pieces in the furnace are likewise of great importance. After the proper number of pieces required for each charge has been determined, a standard chart should be made covering their respective heat treatments, in which should be specified, the time required to bring each charge up to the correct temperature and the length of time that is necessary to hold each charge at this temperature. Detailed instructions should be established covering the method of handling the parts in cooling them from the normalizing or annealing operations or the proper manner of quenching in oil, brine or water, as the case may be. Experience has shown that bringing the steel parts up gradually and uniformly to the desired temperature and then holding them at that temperature until thoroughly soaked through and then subsequently quenching them, produces the best physical properties.

#### PYROMETER EQUIPMENT

In the use of pyrometer equipment a great deal of practical judgment should be used. The thermocouple should be placed in close contact with the work so that when the eye of the furnace

operator sees the work to be heat treated he will also see the hot junction of the thermocouple. He will then be able to compare more accurately the color of the hot junction of the thermocouple with the parts being heat treated. In other words, if the hot junction of the thermocouple and the parts to be heat treated have exactly the same color they will be practically of the same temperature. All of the thermocouple leads should be connected to a potentiometer type of temperature indicator located in the central station and by use of a selective type of switch the temperature checker observes and records at five-minute intervals the temperature readings of each thermocouple. A 24-hour temperature record sheet is kept in operation, and the temperature of the two thermocouples of each furnace is recorded every five minutes. This system of checking provides the checker with information as to the temperature of each furnace and with this information he can then operate the signal system which keeps the furnace operator informed as to the temperature of each furnace.

Fig. 1 shows a convenient form used for the recording of the heat treatment of each furnace charge. When a furnace is loaded with parts to be heat treated, the temperature checker fills out this form as follows:

The name of the part, the part number, the order number, the number of pieces in the furnace and the furnace number. In the case of quenching operation he will fill in opposite the operation, the date, the time at which the furnace is loaded (a.m. or p.m.), the temperature of the furnace at the start, the time required to bring the furnace up to the desired temperature, the length of time it is held at the desired temperature, the date and time that the charge is removed from the furnace, the quenching medium used and the number of the automatic temperature recorder operating on that particular furnace.

The automatic temperature recorder is operated independently of the instrument used by the temperature checker, inasmuch as the automatic recorders are used as a check on his reports.

If the pyrometer sheet and heat treatment record form shown in Fig. 1, check as to time and temperature, with the automatic recorder chart, the heat treatment record form is filed as a record of that furnace charge. These are kept for a period of three months and should any difficulty develop during this interval in



the machining of these parts, it is an easy matter to trace the record of heat treatment and observe what happened during the heat treating operation. After three months have elapsed, this particular furnace charge will have been converted into finished parts and turned into the stock room. Consequently, any further record would be unnecessary.

### CONTROL SYSTEM

In this system of control the furnace operators do not worry about the time or temperatures required for each charge. The necessary instructions are all signalled from the central station

Heat treatment record on *Alignment Joints*

Part No. 7817

Order No. 6114

No. Pcs. 40

Fur. No. 19

Oper.	Date	Time		Temp. at Start	Temp. Reach.	Time Req. Hrs.	Held at Temp. Hrs.	Charge Rem.		Quench Me- dium	Re- corder No.	
		A. M.	P. M.					Date	Time			
									A. M.			P. M.
Anneal												
Quench	7/9/23		12.10	1400	1550	3	½	7/9/23		3.40	oil	4
Drawing												
Carburizing												

Remarks

Recorded by \_\_\_\_\_

Fig. 1

by a series of three colored lights, red, white and green, which are placed over each thermocouple. When the green light is burning it indicates that the temperature of that particular thermocouple is too low. When the green and white lights are burning at the same time it indicates that the temperature of that thermocouple is within 20 degrees Fahr. of the desired temperature, and when the white light is burning alone, it indicates that this thermocouple

is at the desired temperature. If the red light and the white lights are burning at the same time this would indicate that the thermocouple is 20 degrees Fahr. or less above the desired temperature. If the red light is burning alone this would indicate that this thermocouple has exceeded the desired temperature by more than 20 degrees Fahr. When the charge has been held the proper length of time at the proper temperature, such as specified by the standard heat treatment chart, all the lights will be burning. This condition will inform the furnace operator that the charge in this particular furnace is ready to be removed. This system of signalling furnace temperatures, readily informs the furnace operator with an indication of the temperature conditions in the furnace which he can easily understand and thereby adjust the burners on his furnaces accordingly.

This system tends to eliminate some of the responsibility of maintaining the correct furnace temperature and makes the work easier for the furnace operator. It usually eliminates the necessity for him to walk the whole length of the heat treating room, to observe the pyrometer and see what temperature he has in each individual furnace. The saving of this time consequently gives him more time to look after the material in the furnace, and provides him with more time to give to the regulation of the temperatures as indicated from the central control system.

As we are all striving to eliminate the possibility of error and increase our efficiency, any methods which reduce the personal equation to a minimum is desirable. This is especially true in the art of the heat treatment of steel. Inasmuch as we are unable to entirely eliminate the personal equation, it behooves us to adopt such equipments and systems which will simplify the various operations and thereby aid the practical heat treater in the most efficient way.

#### EXAMINATION OF TREATED PARTS

In connection with the foregoing mentioned methods of control, after each furnace charge has been quenched and tempered, small specimens are selected at random from each furnace charge. These are brought into the metallographic laboratory where they are sectionalized, polished and etched, and then placed under the

microscope for examination. This method of inspection gives an accurate check on the effect of heating and quenching. In addition to the microscopic examination of heat-treated parts, each piece is given a Brinell hardness test. This method of testing will identify any parts which are not of the desired hardness or in the proper physical condition. This test is very important both from a point of view of a check on the physical properties and a check on the machinability of the piece concerned.

## NOTES FROM THE U. S. BUREAU OF STANDARDS

THERMAL EXPANSION OF ALUMINUM AND VARIOUS IMPORTANT  
ALUMINUM ALLOYS

THE manuscript of what is believed to be a very important paper on the thermal expansion of aluminum and aluminum alloys has just been completed, and it is hoped that it can be published soon by the Bureau.

This paper gives data on the thermal expansion of four samples of aluminum and fifty-one samples of important aluminum alloys. The preparation, chemical composition, heat treatment, etc., are included. Most of the specimens were examined in the range from room temperature to about 500 degrees Cent. (932 degrees Fahr.), and typical expansion curves of the various samples are shown and discussed. In some cases the data on expansion were compared with the equilibrium diagrams of binary alloys. After the expansion tests, the changes in length from the original lengths were determined.

A description of the apparatus used in this research and a review of available information obtained by previous observers on the thermal expansion of aluminum and some of its alloys are included.

## HIGH TEMPERATURE TESTS OF METALS

This work, which was mentioned in the last Bulletin, has been continued. The maintenance of the apparatus is a constant problem and a great deal of time was spent during the month in improvements and repairs.

Twenty-five short-time tests were made on specimens of a well known heat-resisting alloy. Insofar as the specimens were themselves comparable, the results were consistent with the composition, but many of the cast specimens were defective, so that only those which appeared to be sound were tested. Melts of heat-resisting alloys in about 20 pound heats are badly needed, and a special crucible furnace is being constructed in which the Bureau hopes to prepare these alloys.

## COATING WOOD WITH SPRAYED METAL

In California and other warm climates wood is attacked by white ants, and lead cable sheathing suffers from the cable borer or "short circuit beetle." The latter cuts his way through lead with ease if he can find a suitable fulcrum from which to work. A possible method of keeping him out would be by covering the cable at points likely to be attacked with a coating so hard that he could not bore through it, and the Bureau believes that spraying a hard metal over the lead may solve the problem. Apparatus similar to that recently developed for the Signal Corps could be used.

Information obtained from Technical News Bulletin No. 86, published by the Department of Commerce, Bureau of Standards, Washington.

Infected wood containing beetles about ready to emerge has been supplied by the Department of Agriculture, and has been sprayed with various metallic coatings to find out whether the beetles can cut through the metal.

Sound wood of several species has also been coated, and the Department of Agriculture will see whether the beetles can drill through it.

#### EFFECT OF ULTRA-VIOLET LIGHT ON POLISHED METALS

In connection with some of the Bureau's work it has been noted that ultra-violet light appears to accelerate the atmospheric corrosion of polished metal surfaces. That is, portions of the metal exposed to the light became tarnished while parts which had not been exposed remained bright. These results may lead to the development of a method for indicating the liability of metals to corrosion or the formation of a superficial oxide film. A few specimens of steel and brass have been prepared, and the work will be continued.

#### THE USE OF PAINT AS A MEANS FOR DECREASING OR INCREASING THERMAL RADIATION

Some time ago the Bureau carried out a series of tests to discover the effect of different kinds of paint or the absence of paint on the heat radiated from various surfaces.

Recently the data have been published as Technologic Paper No. 254, "Emissive Tests of Paints for Decreasing or Increasing Heat Radiation," which may be obtained from the Superintendent of Documents at 5 cents per copy.

Data are given on the emissivity of sheet iron, cotton duck, roofing material, artificial leather, etc., covered with white paint, vitreous enamel, aluminum paint, etc.

It was found that aluminum paint emits only 30 to 50 per cent as much thermal radiation as the unpainted material, the white paint, vitreous glass enamel, or other non-metallic coatings.

These results should prove useful in reducing the heat radiated from the under side of roofs, tents, awnings, and automobile tops. For instance, a coating of aluminum paint applied to an automobile top reduces by 50 per cent the heat radiation from the under side, while if used on the under side of a cotton duck tent, it will shut out 85 per cent of the heat rays.

Considering the opposite side of the question, to obtain the greatest heating efficiency from a given size of house radiator, aluminum and bronze paints should not be used. Since however such devices are essentially heat *convectors* and not radiators, a gain of only 15 to 20 per cent in heat dissipation can be expected if a non-metallic instead of a metallic paint is employed.



## STANDARD SAMPLES

Renewal No. 8C, Bessemer 0.1 carbon steel, is in the hands of the co-operating analysts and, judging by the number of reports which have already come in, this sample will be ready to be sent out with a provisional certificate about the time the Bulletin is published.

The new sample of high carbon ferro-chromium, No. 64, is also in the hands of the co-operating analysts, and it is planned to issue this not later than July 1.

Renewal No. 9b, Bessemer 0.2 carbon steel, has just been machined and will probably be ready to be sent to the co-operating analysts at the time this Bulletin appears.

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NOTES FROM THE U. S. BUREAU OF MINES\*

## REDUCTION AND CARBURIZATION IN IRON SMELTING

**E**XPERIMENTAL work by Department of the Interior metallurgists on reduction of iron oxide by carbon monoxide is progressing rapidly at the Northwest experiment station of the Bureau of Mines at Seattle, Wash. Reduction tests have been made at temperatures varying from 700 to 1000 degrees Cent. (1292 to 1832 degrees Fahr.) at times from 1 hour to 5 hours on sizes up to 2 inches. Preliminary observations indicate that size has more influence than any other factor on rapidity of reduction. A piece 2 inches in diameter was not completely reduced at 900 degrees Cent. (1652 degrees Fahr.) in 5 hours. Magnetite reduces only about half as fast as dense hematite. A new and apparently accurate method has been developed for the determination of metallic, ferrous, and ferric iron in the same sample.

## IRON MINING METHODS IN ALABAMA

A detailed study of conditions affecting mine support and mine subsidence in the red iron ore mining district of Alabama is being made by Interior Department Engineers attached to the Southern Experiment Station of the Bureau of Mines, Birmingham-Tuscaloosa, Alabama. The work includes a study of strength of ore and top-rock, failure of pillars, and general conditions affecting mine support. The failure of top-rock has been given special attention, together with the determination of angle of break, both of these matters being closely connected with the problem of mine subsidence. Some three hundred separate observations on angle of break have been made both

\*Information obtained from June, 1924, Press Memorandums of the Department of the Interior, Bureau of Mines, Washington.

on the surface and under ground. In connection with the proposed tests on crushing strength and deformation under pressure, 125 iron ore samples, cut into cubes and columns, have been sawed by diamond and carborundum saws and rubbed to bone finish. Samples of top-rock, rough ore and draw-slate have been collected and some fifty bars have been cut for binding strength tests. Crushing tests will be conducted at the Bureau of Standards, Washington, D. C., while bending strength tests will be made at the Carnegie Institute of Technology, Pittsburgh.

#### LOSSES IN COPPER SMELTER SLAGS

A study of metal losses in copper smelters of the Southwest has been completed by the Department of the Interior, through the Bureau of Mines. Data were collected on the conditions existing at the various smelters, the various modes of operation, the character of ores charged, and the fluxes employed. The object of this study was to determine as closely as possible, the causes of losses of metal into copper slags, in smelting low-grade refractory ores which in addition to copper carry one or more of other metals, gold, silver, lead and zinc. With this information in hand, the Bureau of Mines metallurgists should be able to formulate a program of research having for its object the prevention, to a greater extent than is now customary, of the metal losses in slags.

#### MELTING FOUNDRY IRON

A series of tests in the making of synthetic cast iron in a commercial electric furnace has been completed by Department of the Interior engineers at the Seattle, Wash., experiment station of the Bureau of Mines. Both synthetic gray iron and mild steel were produced in alternating runs without trouble. Miscellaneous steel scrap of all kinds was charged into the furnace to produce various grades of iron. The results show that, under the conditions in this foundry, the synthetic product can compete with cupola iron, and is superior in quality and strength. These results will be applied in the melting of sponge iron, and in the melting of scrap at foundries. These experiments were made in a commercial direct-arc acid-lined furnace of 3000 pounds capacity. Soft machinable iron with a transverse strength of 5600 lbs. on a standard bar was repeatedly made. Without the opportunity for direct comparison, it seems apparent that carburization is more difficult in an acid-lined furnace than in a basic hearth. Retort carbon, clean crushed coke with about 14 per cent ash, and coke breeze containing considerable ash and dirt were compared as carburizers, with the result that the retort carbon was found to be decidedly superior to the crushed coke and the coke breeze just as definitely inferior to the other two. Except for its bulkiness, which makes charging more difficult, tin plate scrap was melted as readily as other steel scrap. Under normal commercial conditions, excepting only those where some

unusual trouble or delay was encountered, the average power consumption was 710 K. W. H. per ton. That figure could be reduced at least 100 K. W. H. under more nearly ideal conditions. All these results corroborate exactly the results obtained in experimental work on synthetic gray iron previously made by the Bureau of Mines.

#### COMPENSATION INSURANCE FOR METAL-MINE WORKERS

When a metal-mining company takes out a workmen's compensation insurance policy, it does so to relieve itself of its uncertain and variable financial liability under laws requiring payment to employees for lost-time accidents, thereby passing the liability on to the insuring agency, states Byron O. Pickard, district mining engineer, Department of the Interior, in Serial 2607, just issued by the Bureau of Mines. For this service, or rather for the assumption of the risk, the insuring agency charges the mining company a price, or in insurance parlance, "a premium." The insuring agency depends upon a volume and variety of business to average the losses incurred by its individual policy holders, and determines its price to cover losses that are suffered and its cost of doing business. It is generally known that all types of insurance are founded on the theory of probability applied to large groups of risks. Workmen's compensation insurance is no exception, and the average price paid therefor must be based on the frequency and severity of accidents in the particular industry or branch of industry under consideration. The frequency and severity rates are determined by statistics, which, of course, unless standardized, kept carefully and consistently, and analyzed properly, are liable to be inaccurate and misleading. A study of premium rates for compensation insurance for underground metal-mine workers is outlined in Serial 2607, copies of which may be obtained from the Department of the Interior, Bureau of Mines, Washington, D. C.

#### ANALYSIS OF ALUMINUM AND ITS ALLOYS

In connection with its investigations in the metallurgy of aluminum and aluminum alloys, the Bureau of Mines, Department of the Interior, has developed certain methods of chemical analysis for these materials as well as for aluminum ores and other aluminum works materials. The purpose of an investigation now being conducted at the Pittsburgh experiment station of the Bureau of Mines is to prepare a compendium of methods of analysis and to carry out research work in this field.

Methods have been developed for the direct determination of aluminum, and the ordinary methods of analysis for copper, silicon, iron, zinc, nickel, titanium, carbon, nitrogen, and other impurities or additive elements contained either in aluminum or its light alloys have been compared. A bulletin descriptive of the results of the work is in progress of writing.

#### REDUCTION AND CARBURIZATION IN IRON SMELTING

The purpose of investigation of reduction and carburization in iron smelting, being conducted by the Department of the Interior at the Seattle, Wash., experiment station of the Bureau of Mines, is to determine the chemical reactions occurring in the process of producing pig iron, especially in the electric furnace. Previous work done at this station on the preparation of sponge iron and also on the carburization of iron to produce synthetic pig iron have brought out some interesting and valuable conclusions regarding the chemistry involved in the production of pig iron. In this study such work will be continued with the hope of definitely establishing all of the conditions required for reduction of iron ores and carburization of iron to produce pig iron.

#### TRANSMISSION OF HEAT FROM A MOVING GAS TO A SOLID

Not enough is known regarding the heat interchange between a moving gas stream and a bed of solid particles to be able to predict with any degree of certainty the conditions which will be established when the size of the particles, the temperature of the inlet gas and its velocity are known with a fair amount of accuracy. Department of the Interior investigators attached to the Minneapolis experiment station of the Bureau of Mines are making a study of the transfer of heat when air at varying temperatures and rates of flow is forced through solid particles differing in size, density and heat conductivity. The results of such a series of experiments will be applicable to a number of commercial processes, including the blast furnace.

Other experiments are being conducted to study the transfer of heat through steel pipes, in order to acquire information useful in designing pre-heaters and recuperators having pipe elements. Such factors as size of the pipes, flow of air and temperature of the gas used for heating will be varied over an appropriate range. The suitability of calorized pipes for use at high temperatures, as well as the effect of calorizing upon heat transfer, will also be studied.

#### MICROSCOPIC STUDY OF ORES

The chief function of the microscopic laboratory of the Interior Department, located at the Intermountain Station of the Bureau of Mines, Salt Lake City, is the application of microscopic methods of investigation for obtaining data that cannot be satisfactorily obtained by chemical or other methods. Much of this work is done in determining the physical and mineralogical characteristics of those ores that have been termed complex or whose treatment involves an intimate and exact knowledge of these features.

This work consists of the identification of the minerals of commercial value, their manner of occurrence and association with each other, and their relationship to the gangue or worthless portion of the ore. These data are essential in predetermining the fineness of grinding required to unlock the

mineral particles and thus ensure favorable conditions for their recovery and separation into marketable products with a minimum of economic waste.

Special attention has been given by the Bureau of Mines to the study of the mode of association of silver-bearing minerals in the low-grade and complex sulphide and oxidized ores and it has been shown by this work that many conclusions based on the results obtained by chemical analyses and fire assays were erroneous and misleading.

Photomicrography plays an important part in presenting visual evidence of the conditions that are found to exist in the ores studied and it is, therefore, freely employed and constitutes a graphic representation of the descriptive matter in reports.

In connection with mineragraphic investigations, the preparation of the mineral samples and milling products for microscopic study constitutes a problem of vital importance to the success and accuracy of the subsequent microscopic investigations. This subject has been the object of considerable study and experimentation and important data along this line are being accumulated. Many details of a practical nature yet remain to be worked out.

The subject of etching with acids and other reagents as a determinative procedure in mineragraphic work has been given considerable attention.

#### PHYSICAL CHEMISTRY OF REDUCTION OF METAL OXIDES

It is easier to discuss possible improvements in the metallurgy of any metal if the fundamental principles are known. In order to improve the metallurgy of zinc by distillation it is necessary to know a great deal more about the equilibrium diagrams involving zinc metal, zinc oxide, carbon, carbon dioxide and carbon monoxide. Some work has already been done along this line by the Interior Department at the Rolla, Mo., station of the Bureau of Mines, but the matter will be taken up more extensively at the Bureau's Berkeley, Calif., station. After the work on zinc is done, probably more work will be done on iron oxides, and possibly on lead and copper oxides and after that on the less commonly used metals. The reduction of aluminum and magnesium by the help of carbon will always be difficult until the fundamental physical chemistry underlying these reductions has been studied. This general work will be taken up by the Bureau of Mines and the particular phases given attention from time to time. It is hoped that ultimately a bulletin can be written giving all the work and discussing the whole general subject, both from an experimental and from an historical standpoint. At present it is felt that such a bulletin should bring together all the fundamental information and figures on the more common metals.



## Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column - Members Submitting Discussions Are Requested to give Their Names and Addresses

To the Editor:—

I was pleased to read the very interesting discussion in the February, 1924, issue of TRANSACTIONS, of Professor Sauveur's paper on granulation.

I was especially interested in the discussion of Professor O. W. Ellis. The diagram which he used, explains in an excellent manner, the importance of the delta-gamma transformation. Consequently, I investigated to see who is the authority on the figure he used, but I was unable to find any new experimental data, other than that of Ruer and Klesper, which I am using myself. I then consulted Honda's paper in the Journal of the Iron and Steel Institute, 1922. There I found a certain clew. The figures were apparently misprinted, and in place of 0.18 per cent, the figure 0.81 per cent was used. That becomes clear from the authority he quoted and from his original paper in Science Papers (From Japanese into English).

I am writing this in order to explain why I am using the old figures, in place of the new, which apparently are even more useful for my hypothesis, in my paper to be presented at the 1924 Convention of the American Society for Steel Treating. (Paper published in June, 1924, issue of TRANSACTIONS.)

33, Elvaston Place,  
Queen's Gate,  
London, S.W. 7, England.  
April 2, 1924.

(Signed) N. Belaiew.

The above letter was redirected to Professor O. W. Ellis, who replies as follows:

To the Editor:—

In reference to my discussion of Professor Sauveur's paper on the "Crystallization of Iron," Colonel Belaiew has made special reference to the diagram showing the effect of carbon on the A4 point of iron which appears as Fig. 1 of my discussion.

This diagram was based partly on the statements made by Professor Honda on page 384 of Vol. CV of the Journal of the Iron and Steel Institute, and partly on the diagram which appears as Fig. 1 on the same page of the same volume. Unfortunately, I had no access to the original papers by Ruer and his collaborators.

If reference be made to page 384 of the above Journal, it will be found that Honda, first, states that "the melt 0.38 per cent carbon is in equilibrium with gamma and delta irons of the concentrations 0.81 per cent carbon and 0.07 per cent carbon respectively," and second, he shows a diagram which appears strongly to confirm the view that his statement should read "the melt of 0.81 per cent carbon is in equilibrium with gamma and delta irons of the concentrations 0.38 per cent carbon and 0.07 per cent carbon respectively."

It appears from Colonel Belaiew's letter that my deductions were unfortunately in error and that the peritectic reaction which occurs at 1486 degrees Cent. is actually between a melt containing 0.38 per cent of carbon and a solid solution of carbon in delta iron (which might, in honor of the noted investigator of the effect of carbon on the gamma-delta transformation be referred to as Ruerite) containing 0.07 per cent of carbon. I wish to thank Colonel Belaiew for directing my attention to this error.

University of Toronto,  
Toronto, Ontario, Canada.  
May 10, 1924.

(Signed) O. W. Ellis.

In reply to Professor Ellis' answer, Colonel Belaiew comments as follows:

To the Editor:—

I take this opportunity to confirm how very much interested I am in Professor Ellis' discussion of Professor Sauveur's paper, and to say that I quite agree with the emphasis laid upon the importance of the distectic point. I do not think that the figures, as originally given by Ruer and Klesper will affect the importance of the distectic reaction. I am also inclined to believe that further researches might prove that this reaction is to be extended further to the right.

May 21, 1924.

(Signed) N. Belaiew.

## The Question Box

A Column Devoted to the Asking, Answering and Discussing  
of Practical Questions in Heat Treatment — Members  
Submitting Answers and Discussions Are Requested  
To Refer to Serial Numbers of Questions

### NEW QUESTIONS

QUESTION NO. 129. *Does full annealing chromium and tungsten magnet steel, before hardening, affect the magnetic properties? If so, what is the cause?*

QUESTION NO. 130. *Is there any advantage in using notched-bar impact tests in the inspection of annealed tool steel bar stock? What does such a test show?*

QUESTION NO. 131. *Given an alloy of the brass or bronze type, in which there are no critical transformation points, suppose that through carelessness the metal has been overheated, producing an undesirably coarse crystalline structure, is it possible to refine the grain without remelting or mechanical work?*

QUESTION No. 132. *Given an alloy of the following analysis as cast, would the addition of vanadium to the extent of 0.10 to 0.20 per cent decidedly improve the following physical qualities in either the "as cast" or heat treated alloy? What heat treatment, if any, should be used to develop the following qualities.*

1. Resistance to wear

2. Resistance to dynamic stresses

#### ANALYSIS

1.80 — 2.20 per cent carbon	.04	"	sulphur
.50 — .60 " manganese	.04	"	phosphorus
.30 — .40 " silicon	1.50 — 2.00	"	chromium

### ANSWERS TO OLD QUESTIONS

QUESTION No. 98. *What heat treatment will give a pure martensite structure throughout the hardened area of a piece of steel 6 x 2 x 3½ inches?*

QUESTION NO. 106. *What are the effects of the products of combustion upon both carbon and high-speed steel, when heat treated in open furnaces heated with city gas, coal, coke, fuel oil, etc?*

QUESTION NO. 120. *How does the carbon content affect the secondary hardness of high speed steels?*

*QUESTION NO. 125. What is a suitable test to apply to a carburizing box before installing it in service?*

ANSWER. By R. W. Fuchs, engineer, Blaw-Knox Co., Pittsburgh.

This company has been manufacturing wire annealing pots and tin mill annealing boxes for the past four years. We have found that by filling the boxes with kerosene oil, or an oil equal to it in specific gravity, we have been able to detect any unsound boxes which may contain flaws such as blow holes, cracks, etc. Another test to which this equipment is subjected is a "steam test." With this test, the pot is turned upside down and placed in a water seal and then subjected to a steam pressure that will not blow out the water seal. This likewise will reveal porosity, cracks, etc.

*QUESTION NO. 126. How should steel castings be specified and purchased?*

ANSWER. By M. E. Greenhow, metallurgist, National Brake and Electric Co., Milwaukee, Wis.

Steel castings should be specified and purchased on a given minimum tensile strength, elastic limit, elongation and reduction of area; chemical composition to be consistent with the above requirements. Maximum phosphorus and sulphur .050 (basic); maximum phosphorus and sulphur .060 (acid).

*QUESTION NO. 127. How should tool steel be specified and purchased?*

ANSWER. By M. E. Greenhow, metallurgist, National Brake and Electric Co., Milwaukee, Wis.

This question is rather indefinite as there are many grades of tool steel; therefore the specification on the same, should be determined by the use it is going to be put to and the work it has to do.

*QUESTION NO. 128. What heat treatment, if any, could be given to a steel casting of the following composition which would produce the physical properties as given below?*

Per Cent		
Carbon	0.65	Tensile Strength
Manganese	1.37	Yield Point
Silicon	0.37	Elongation in 2 in.
Phosphorus	0.024	Reduction of area
Sulphur	0.033	

ANSWER. By M. E. Greenhow, metallurgist, National Brake and Electric Co., Milwaukee, Wis.

A 0.65 per cent carbon steel could not be heat treated to produce as low tensile strength as suggested by the question. Why not use a mild 0.30 carbon steel and get better results than suggested and use only a normal heat treatment.

## Abstracts of Technical Articles

### Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

APPLICATION OF PRESSED METAL TO PULLEYS. By S. C. Gaillard, Jr., assistant chief engineer, American Pulley Co., Philadelphia, in *Forging, Stamping and Heat Treating*, June, 1924, page 226.

This article describes the various operations in the manufacture of pressed steel belt pulleys. Today this is one of the most notably successful of the many applications of the pressed metal art.

REFINING METALS ELECTRICALLY. By Larry J. Barton, New Orleans, La., in *Foundry*, June 15, 1924, page 460.

The above article is the first of a series to be published and states that operating costs may be governed by the size of the unit selected. The next chapter of this article will give data on the examination of product which will determine whether acid or basic operation is to be used.

WORK-HARDENING OF VARIOUS METALS. By Edward G. Herbert, president, Edward G. Herbert, Ltd., Manchester, England, in *Iron Age*, June 19, 1924, page 1792.

This article gives three charts of work-hardening tests, showing the results with a British pendulum hardness tester, and states that recent researches with the Herbert pendulum hardness tester have thrown additional light on the subject of work-hardening.

WELDING CAST OR MALLEABLE IRON. By A. H. Jansson, in *Iron Trade Review*, June 19, 1924, page 1632.

Methods used for welding castings at comparatively low temperatures is said to eliminate excessive oxidation of the metal. The above article describes the process and states that welds show satisfactory tensile strengths.

DIRECT PRODUCTION OF IRON. By Edwin Fornander, chief metallurgist, Sandvikens Jernverk, Sandviken, Sweden, in *Chemical and Metallurgical Engineering*, June 9, 1924, page 907.

This is the second part of this article and comprises a critical review of the more important methods that have been used to produce wrought iron from the ore.

MAKING STEEL FOR ORDNANCE USE. By J. B. Rhodes, commander, United States Navy, Washington, in *Iron Trade Review*, May 29, 1924, page 1428.



This article is taken from a paper presented at the spring meeting of the American Iron and Steel Institute, New York City, May 23rd. It states that the reduction of iron oxide to a minimum is essential in the production of steel for this purpose, also phosphorous and sulphur should be eliminated. The quality of the steel is affected by slag. Shop practice instructions are suggested.

**NOTES ON THE TESTING OF METAL STRIP.** By Leslie Aitchison and Leslie William Johnson, in *Forging, Stamping and Heat Treating*, June, 1924, page 230.

The above is taken from a paper presented at the May, 1924, meeting of the British Iron and Steel Institute, and describes the methods and apparatus for making tensile and bend tests on metal strip.

**USE OIL IN MALLEABLE FURNACE.** By B. R. Mayne and Carl Joseph, in *Foundry*, June 15, 1924, page 472.

This article tells of a new method which can be installed whereby oil may be used in malleable furnaces. The same construction may be used as is employed in coal-fired furnaces, and the oil consumption is considered low.

**CHROMIUM—ITS USES AND ITS ALLOYS.** By Dr. Walter M. Mitchell, metallurgist, E. I. du Pont de Nemours and Company, Wilmington, Del., in *Forging, Stamping and Heat Treating*, June, 1924, page 235.

This article states that due to its valuable properties, chromium is extensively used in the steel industry for the manufacture of alloy steels and heat and corrosion resisting alloys.

**MAKING GLOBE VALVE COREBOX.** By Walter C. Ewalt, in *Foundry*, June 15, 1924, page 483.

The above article states that metal boxes are cast from carefully constructed wood master patterns where the foundry output is large, and in many cases the pattern is built up from a number of small segments.

**COMPLEX ACTION OF DEOXIDIZING AGENTS.** By Dr. Federico Giolitti, Turin, Italy, in *Forging, Stamping and Heat Treating*, June, 1924, page 242.

This article was taken from a paper presented at the September, 1923, meeting of the British Iron and Steel Institute and points out that a close study of the process of deoxidation in the open hearth furnace reveals that the action is of a somewhat more complex nature than generally supposed.

**STUDY ALUMINUM HARD SPOTS.** By A. J. Lyon, first lieutenant, United States Air Service, McCook field, Dayton, Ohio, in *Foundry*, May 15, 1924.

This article states that the cause of hard spots in aluminum has been widely discussed and experimental work has been done in an endeavor to

ascertain the cause of this condition. The materials used in this investigation and conclusions reached, are given.

**SULPHUR CONTENT OF THE ACID CHARGE.** By J. West Scotland, in *Journal of the Iron and Steel Institute*, Vol. 31, 1924, page 42.

In this paper is incorporated a discussion of the experiments conducted by the author to determine the stage of manufacture at which sulphur is taken up by the steel. The results showed that a small but steady decrease of sulphur content would occur during the boiling period, if a gas free from sulphur could be used and a vigorous boil maintained.

**TESTS PROPERTIES OF STRIP METAL.** By L. Aitchison and L. W. Johnson, in *Iron Trade Review*, May 22, 1924, page 1361.

The above is an abstract of a paper presented at the annual meeting of the British Iron and Steel institute, London, May, 1924, and describes the performance of an apparatus for determining the stress of strip steel and for bending the product, which greatly simplifies the commercial methods of testing. The extensometer and bend testing machine are also described.

**PRESSED METAL REVOLUTION IN INDUSTRY.** By Arthur L. Green, Buffalo Forge Company, Buffalo, N. Y., in *Forging, Stamping and Heat Treating*, April, 1924.

The above article states that the pressed metal industry is comparatively young and its very existence comes from the demand for standardization and quantity production.

**SELECTING MATERIAL FOR DRAWN PARTS.** By L. N. Brown, inspection division, Maxwell Motor Corporation, in *Forging, Stamping and Heat Treating*, April, 1924.

The author suggests a method for testing sheets and strips to show their suitability for forming and drawing operations and states that all shipments should be carefully stamped.

**DEVELOPMENT OF MODERN EQUIPMENT FOR NITRIC ACID PRODUCTION.** By F. C. Zeisberg, chemical engineer, E. I. du Pont de Nemours and Company, Wilmington, Del.; in *Chemical and Metallurgical Engineering*, Vol. 30, No. 20, May 19, 1924.

The above article was given at Carnegie Institute, March, 1924, and discusses from the equipment viewpoint, the distillation, condensation and absorption steps in the sulphuric acid-niter process.

## Reviews of Recent Patents

By

NELSON LITTELL, Patent Attorney

110 E. 42nd St., New York City

Member of A. S. S. T.

**1,492,973, Steel Alloy, Charles T. Evans, of Titusville, Pennsylvania, assignor to Cyclops Steel Co., of New York, N. Y., a corporation of New York.**

The inventor of this patent proposes to produce a steel alloy of the nickel-chromium type which possesses the usual hardness, toughness and resistance to corrosion of nickel-chromium steels, but which at the same time may be hardened by ordinary heat treatment.

The patent discusses the general advantages of nickel-chromium steels and the fact that with certain compositions, the steel which is produced therefrom is so hard it cannot be machined and with other compositions the steel is such that it can be machined, but the machined articles cannot be satisfactorily hardened by the ordinary heat treating processes. It is the purpose, therefore, of this inventor to produce a nickel-chromium steel which will have the usual advantages of this type of alloy and which at the same time will be soft enough for machining and can be subsequently hardened by ordinary heat treatment. To do this he adds to the nickel-chromium steel, a refractory metal of the carbon group, for example, zirconium or titanium, or both and silicon. One example of the new alloy is, nickel 7 per cent, chromium 8 per cent and 3.25 per cent of silicon, zirconium and titanium. Various other compositions may be used within the spirit of the invention providing the ratio of the combined silicon, zirconium and titanium added is proportioned to the total nickel or chromium content to produce the desired properties.

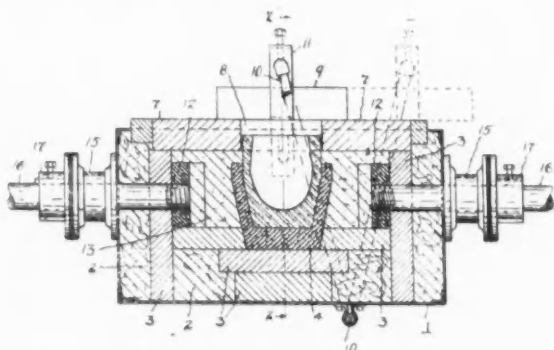
**1,493,039, Process for the Manufacture of Metals or Alloys poor in Carbon and Silicon, Bo Michael Sture Kalling and Sven Dagobert Daniell or Trollhattan, Sweden, assignors to Aktiebolaget Ferrolegeringar, of Stockholm, Sweden, a limited joint stock company.**

This invention relates to a process of manufacturing alloys low in carbon and silicon and principally to the manufacture of these alloys in an electric furnace without the passage of carbon into the alloy during the manufacturing process. Advantage is taken of the fact that silicon is able to expel the carbon from the metal or alloy, and the charge is made up preferably with at least 10 per cent silicon. This alloy, rich in silicon, is melted together with substances capable of oxidizing the silicon such as oxides of chrome, vanadium, manganese, tungsten, iron, nickel, etc., and to prevent the carbon passing into the charge from the electrodes, the voltage drop between the point of the electrodes and the charge is kept above 70 volts, the refining

operation is continued under these conditions until the silicon content is reduced to the desired point and the charge is tapped.

**1,493,731, Electric Furnace, Charles A. Caldwell, of Cleveland, Ohio, assignor to the Electric Railway Improvement Company, of Cleveland, Ohio, a corporation of Ohio.**

This invention relates to an electric furnace of the resistance type in which granulated material such as granular carbon is used as the resistance material. The furnace comprises of box portion 1, provided with suitable insulating lining 2, and with blocks of fire-clay or heat resisting material 13 for supporting the crucible, holder 4 which is of substantially the shape of



the crucible and composed of graphite. The current is conducted into the furnace through the terminals 17 to the electrodes 12, and from there through the granular resistance material 13 to the crucible holder 4 and crucible 5, by providing a crucible holder 4, surrounding the crucible as is illustrated, the course of the heat through the granular material is diverted away from the bottom of the furnace chamber and is concentrated around the holder or crucible therein which increases the efficiency of the furnace and decreases the tendency to burn out the bottom.

**1,493,191, Alloy, Anthony G. de Golyer, of Brooklyn, New York.**

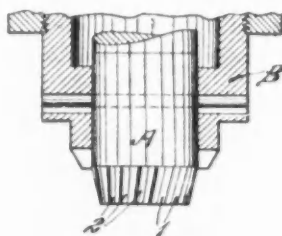
This patent discloses a new alloy composed essentially of iron, chromium and boron and which may contain in addition, elements such as carbon, silicon, nickel, aluminum, etc. The new alloy has marked resistance to oxidation at high temperature, resistance to the action of many acids and alkalis, high tensile strength, etc.

The claims cover an alloy composed of chromium, iron, and boron in appreciable amounts up to 15 per cent, together with various other alloying ingredients such as carbon, tungsten, manganese, nickel, cobalt, etc. The alloy may be produced by melting together predetermined proportions of iron, chromium and boron or by adding the boron to the molten iron and chromium.

**1,492,568, Device for Use in Quenching Annular Articles.** Marcus T. Lothrop, of Canton, Ohio, assignor to the Timken Roller Bearing Company, of Canton, Ohio.

This patent is for a device for sizing and quenching annular articles, such as cups and cones used for roller bearings and the like to prevent distortion of these articles during the quenching operation.

The device comprises a plug A with a frustro-conical end portion which is fluted to provide ridges 1 and grooves 2 therein which are oblique to the



axis of the plug. In the use of this device, the hot cup or cone is centered upon the quenching plug and the quenching liquid applied thereto, during the quenching operation, the cup or cone shrinks against the rim which supports the cup at close intervals so as to greatly minimize the tendency of the plug to distort while at the same time, the grooves 2 permit the circulation of the quenching liquid on all sides and rapid cooling of the cup.

**1,494,393, Method of Making Alloys,** Richard Walter, of Dusseldorf, Germany.

This invention relates to a process of producing high silicon iron for use in chemical apparatus, etc.

To produce the alloy, the component or iron and silicon in lump form are dumped into a simple reverberatory furnace in roughly intermixed state. The furnace is then heated to a temperature at which the exothermic reaction between the silicon and iron is initiated which will be several 100 degrees Cent. below the fusing point of the ingredients. When this temperature is reached the contact of the silicon and iron will start the reaction with an almost instantaneous flash throughout the entire mass and the temperature of the charge almost instantaneously rises, resulting in complete liquefaction of the charge and the forming of a homogenous iron and silicon alloy. The charge can then be refined and poured in the usual manner.

In lieu of pure silicon, the inventor has found that high-grade ferro-silicon (80-90 per cent) may be used.

**1,495,446, Case-Hardening Compound,** Emil Schlehahn, of Ardmore, Illinois.

This invention relates to a new case hardening compound and process of

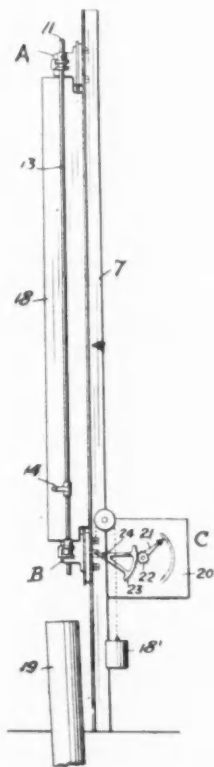


case hardening. The new compound is composed of two parts leather charcoal, three parts potassium carbonate; one part ammonium chloride and one part kainite.

The inventor states that if the steel articles are heated to around 1600 degrees Fahr. for three-quarters of an hour packed in this compound, a case of  $\frac{3}{4}$  of an inch will be produced. Longer heating will produce a deeper case.

**1,492,804, Heat Treatment of Metals and Apparatus Therefor, Harry P. MacDonald, of Montclair, New Jersey, and Angus S. MacDonald, of Great Neck Station, New York, assignors to the Snead & Co. Iron Works, of Jersey City, New Jersey, a corporation of New Jersey.**

This apparatus provides a means for readily determining the point of decalescence of a rod or tube undergoing heat treatment and for stopping the heat treatment at that point and quenching the rod or tube. The ap-



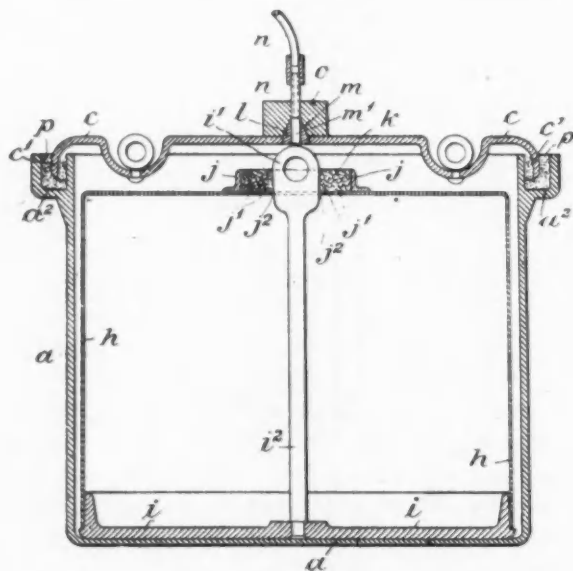
paratus comprises a supporting frame 7 having an upper clamping block A, rigidly secured thereto and a lower clamping block B which is movably connected with the support 7. Electrical connections are provided on each of the blocks A and B and the rod 13 provided with a handle 14 passes between the

blocks, permitting simultaneous opening or closing of the clamping portions of the blocks.

In the use of the device, the rod or tube 11 to be heat treated is inserted through the clamping blocks A and B and the electric current is turned on to heat the rod, by its internal resistance, to the proper quenching temperature. The movable block B is connected by means of a rack Sector 23 to a pinion 22 provided with an indicator 21 which passes over a suitable scale 20 so that when the rod expands under heat, it moves the block B and the amount and rate of expansion is indicated by the movement of the pointer 21 over the scale 22. Advantage is taken of the fact that at the point of decalescence, the expansion of the rod pauses temporarily and when this point is indicated by the pause in the movement of the pointer 21, the handle 14 is actuated to release the rod 11 from the clamping blocks A and B and to automatically drop it into the quenching tank 19.

**1,493,838, Annealing Pot, William Barron and Charles A. Barron, of Preston, England.**

This patent relates to an annealing pot composed of an outer member *a*, a removable lid *c* which rests in the sand seal in flange *a*<sup>2</sup>, a lifting plate *i* in the bottom of the pot *a*. A cover *h* rests upon the lifting plate and sur-



rounds the lifting rod *i*<sup>2</sup> and is provided with a receptacle *j* having a plurality of holes *j*<sup>1</sup> in the bottom thereof and packed with charcoal *k*. The cover *c* is provided with a conical nozzle *m* upon which rests a weight *o* having a conical chamber adapted to form a gas-tight connection with the nozzle *m* and a pipe *n* for the admission of non-oxidizing gases into the pot during the cooling process. The materials to be annealed are placed inside the hood

and during the heating process, the weight o and the pipe n are removed. The charcoal in the receptacle j and the gases which issue from the articles being heated prevent any entrance of air into the pot during the heating operation. When the heating is completed, the weight o and the gas pipe is placed in position and a non-oxidizing gas is forced into the pot as the cooling proceeds. In this manner the metal articles being treated or annealed inside the hood are kept bright and prevented from oxidizing.

**1,494,011, Method of Melting Manganese Steel, Wesley G. Nichols, of Chicago Heights, Illinois, assignor to American Manganese Steel Company, of Chicago, Illinois, a corporation of Maine.**

To increase the availability of manganese steel scrap as a commercial product and to reduce the loss of manganese in the melting of steel scrap, this inventor proposes to melt the scrap in a furnace which is rendered as basic and free from oxygen bearing environment as practicable, and also to provide a readily oxidizable ingredient at the level of and above the slag line which will take up the oxygen of the slag and leave the slag more nearly neutral and hence with little affinity for any portion of the manganese that may enter the slag. By thus providing a basic furnace lining and keeping the slag substantially free from oxygen or other oxidizing influence, the loss of the manganese is reduced to a minimum.

In the practice of the invention, the furnace is lined with any suitable basic material and at and above the slag line, the lining contains a metalliferous ingredient, preferably metallic iron which has sufficient affinity for oxygen to be readily oxidized by the oxygen in the slag and thereby reduce the oxygen content of the slag. The inventor prefers to use what is commercially known as "Metal-kase" brick, which consists of a sheet metal jacket filled with magnesite for this purpose.

## News of the Chapters

### SCHEDULED REGULAR MEETING NIGHTS

**F**OR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list communicate with the National office in order that the list may be as complete as possible.

Boston—Third Thursday.

Cleveland—Fourth Friday, Cleveland Engineering Society rooms, Hotel Winton; meeting at 8 p. m.

Chicago—Second Thursday.

Hartford—Tuesday nearest 10 of month.

Indianapolis—Second Monday.

New Haven—Third Friday.

New York—Third Wednesday, assembly room, Merchants Association of New York, ninth floor, Woolworth Building.

Philadelphia—Last Friday, Engineers' Club.

Tri City—Third Thursday.

### BOSTON CHAPTER

**T**HE Boston chapter of the American Society for Steel Treating held their annual and final meeting on Friday, June 6th, 1924, at the Engineers' Club. The members gathered for a banquet which took place at 6:30 p. m., during which time entertainment was furnished by "The Singing Dancing Trio." Following this, a business meeting was held, the secretary giving his report for the year on the growth of the chapter membership as well as the financial report. A motion was made that the chairman appoint a committee to investigate the advisability of the chapter joining the Affiliated Technical Societies of Boston. Another motion was made that a committee be appointed by the chapter chairman to investigate the printing of a year book listing the chapter membership. These committees will report to the executive committee during the summer. The new officers for the ensuing year were elected at this meeting. They are as follows: V. O. Homerberg, chairman; J. M. Darke, vice-chairman; secretary-treasurer, G. C. Davis; and H. E. Handy and L. E. Zurbach, members of the executive committee. Following the business meeting, Dr. C. B. Waterhouse, professor of metallurgy, Massachusetts Institute of Technology, Cambridge, delivered an address entitled, "The Greatest Metal." The metal referred to was iron and Dr. Waterhouse pointed out that the wonderful property of iron in alloying with other metals gives results entirely different from the original material. The effect of nickel, chromium, and manganese when alloyed with iron was shown and it

was pointed out how these various alloys differed from each other in magnetic, tensile strength and other properties.

The meeting closed with a vote of thanks to the retiring executive officers who had so successfully conducted the affairs of the chapter for the past year.

#### CHICAGO CHAPTER

The Chicago chapter of the American Society for Steel Treating held a meeting on Thursday, May 8th, at which time an excellent paper was given by Harold Wood of the Wyman Gordon Company, Ingalls-Shepard Division, Harvey, Ill., entitled, "The Crankshaft and Its Scientific Development." Following this presentation, the new officers for the year 1924-25 were elected: R. G. Guthrie, chairman; J. L. Walker, vice-chairman; A. G. Henry, secretary-treasurer; E. J. Gossett, G. D. Haines and A. F. Boissoneau, members of the executive committee. This meeting was very well attended.

The chapter held their third annual outing at the Hartmann House, Wheeling, Ill., on Saturday, June 21, 1924. Dinner was served at 2:00 p. m., after which time music and other entertainment was furnished for the members of the chapter and their friends.

#### CINCINNATI CHAPTER

At the May 8th meeting of the Cincinnati chapter of the American Society for Steel Treating, the following officers were elected: Dr. J. Culver Hartzell, chairman; E. P. Stenger, vice-chairman; Fred L. Martin, secretary-treasurer; C. H. Waldo, W. Kinsey, J. H. Nead, R. T. Hazelton, and G. A. Muenzemaier, members of the executive committee. This chapter has had a very successful year and expects that 1924-25 will be a banner year.



The members of the Cincinnati chapter were invited to visit the American Rolling Mill Company, Middletown, Ohio, on June 12th. The party left Cincinnati at 10:30 a. m. and arrived at the plant at noon, where luncheon was served. In the afternoon, the members and their friends made an inspection



of the plant through the courtesy of the company. A photograph of the party, taken at the American Rolling Mill Company is shown.

#### CLEVELAND CHAPTER

The Cleveland chapter of the American Society for Steel Treating held a meeting on Friday, June 6th, at 8:00 p. m., in the Cleveland Engineering Society Rooms, Hotel Winton, at which time J. V. Emmons, metallurgist, Cleveland Twist Drill Company, presented a paper entitled, "Tool Hardening Problems." New officers for the coming year were elected at this meeting. They are as follows: chairman, H. A. Schwartz; vice-chairman, H. H. Smith; sec'y-treas., A. S. Townsend; Executive Committee: R. S. Archer, D. M. Gurney, C. B. Sawyer, E. G. Pierce, G. H. Bierman and W. D. Bell.

#### GOLDEN GATE CHAPTER

This chapter held a meeting on Wednesday, May 14, 1924, at the Industrial Gas Display Laboratory of the Pacific Gas and Electric Co., San Francisco, Calif. Walter Grothe, C. L. Best Tractor Co., San Leandro, Calif., was the speaker of the evening, choosing for his subject, "Case Hardening as Applied to Best Tractors." Mr. Grothe's remarks were received with a great deal of interest and the discussion which followed was interesting and prolonged. The officers for the coming year were elected at this meeting. They are as follows: chairman, P. L. Bannon, president, Pacific Gear and Tool Works, San Francisco, Calif.; vice-chairman, F. H. Pelle, Pacific Gas and Electric Co., San Francisco, Calif.; secretary-treasurer, D. Hanson Grubb, Pacific Scientific Co., San Francisco, Calif.; Executive Committee: A. N. Armitage, Columbia Steel Corp., Pittsburg, Calif.; Frank R. Drake, Johnson Gear Co., Berkeley, Calif.; T. S. Hutton, Ludlum Steel Co., San Francisco, Calif.; Prof. Welton J. Crook, Box 985, Stanford University, Calif.; G. F. Hickock, Hickock and Hickock, San Francisco, Calif.; J. Eastwood, American Forge Co., San Francisco, Calif.; Walter Grothe, C. L. Best Tractor Co., San Leandro, Calif.; Prof. A. B. Domonoske, University of California, Berkeley, Calif.; and E. Downing, Hoover Spring Co., San Francisco, Calif.

#### HARTFORD CHAPTER

The Hartford chapter of the American Society for Steel Treating held a meeting on May 20th, at which time J. V. Emmons, metallurgist, Cleveland Twist Drill Co., Cleveland, addressed the members, choosing for his subject, "Tool Hardening Problems." Mr. Emmons covered in particular the hardening of high speed steel, calling attention to the necessity for sound steel, followed by careful design of the tools to eliminate danger from cracking in the hardening. This presentation was followed by a lengthy discussion. This was illustrated with excellent slides showing the various structures obtained in the treatment of high speed steel in various ways, explaining the advantages and disadvantages as represented by these treatments. The fol-

Following new officers were elected for the ensuing year: chairman, L. A. Lanning; vice-chairman, B. S. Lewis; secretary-treasurer, E. D. Lambert; Executive Committee: J. J. Curran, A. H. d'Arcambal, H. I. Moore, R. W. Woodward, J. M. Washburn, J. L. Koster, Chas. Olsen, A. J. Trappe, and A. J. Weaver.

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#### LEHIGH VALLEY CHAPTER

At the June 2nd meeting of the Lehigh Valley chapter of the American Society for Steel Treating the following officers were elected for the ensuing year: chairman, A. P. Spooner; vice-chairman, G. C. Lilly; secretary-treasurer, B. F. Shepherd; Executive Committee: W. R. Shimer, F. C. Martin, A. C. Moyer, S. P. Koch, H. S. Brainerd, A. E. Fowler, F. Palmer, and R. H. Christ.

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#### LOS ANGELES CHAPTER

The Los Angeles chapter of the American Society for Steel Treating elected the following new officers at their May 7th meeting: chairman, W. H. Laury; vice-chairman, C. A. Stiles; secretary-treasurer, W. L. Johnson; Executive Committee: Edward Black and C. S. Sorenson.

The chapter held its regular dinner meeting on Wednesday evening, June 4th, in the dining room of the Los Angeles Creamery. Following the dinner and the transaction of business, the event took the form of a "silent meeting," with a moving picture as the source of instruction and interest. "The Heat Treatment of Hupmobile Automobile Parts" was the film shown for the first time on the Pacific Coast. Interest was carried throughout the picture by having the physical properties, resulting from the various heat treatment processes, tested following the operations. Micrographs were interspersed to show the effect of various heat applications to grain growth. In addition to the regular members and friends, the sales and service force, numbering about sixty, from the Greer-Hobbins Co., Pacific Coast distributors for the Hupmobile, were presented, headed by Mr. Harris, general sales manager.

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#### NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held a meeting at Waterbury, Conn., on May 23rd, at which time L. A. Lanning, assistant metallurgist, New Departure Manufacturing Co., was the speaker for the evening, choosing for his subject, "Quality Heat Treatment as Carried Out in the Ball Bearing Industry." This was a very interesting presentation and a lively discussion followed.

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#### NEW YORK CHAPTER

The following men have recently been elected as officers of the New York chapter of the American Society for Steel Treating for the coming year: chairman, E. E. Thum; vice-chairman, J. O. Rinek; secretary-treasurer,

T. N. Holden, Jr.; Executive Committee: C. H. McKnight, C. H. Von Schlutter, E. F. Cone, H. C. Griswold, and E. P. Gaffney.

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#### NORTH WEST CHAPTER

On May 25th, the North West chapter of the American Society for Steel Treating held a meeting at the Manufacturers' Club. H. W. Dunbar, Norton Co., Worcester, Mass., presented a paper on "Grinding." Inasmuch as Mr. Dunbar is assistant general sales manager of the company he was capable of discussing the subject from all standpoints. The following officers have been elected for the coming year: chairman, G. C. Priester; vice-chairman, W. I. Sweet; secretary-treasurer, Alexis Caswell; Executive Committee: H. A. Anderson, H. K. Briggs, Norman Conn, W. B. Lindquist and D. Tissing.

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#### PITTSBURGH CHAPTER

The following men were recently elected as officers of the American Society for Steel Treating for the coming year. They are as follows: chairman, DuRay Smith; vice-chairman, O. B. McMillen; secretary-treasurer, H. L. Walker; Executive Committee: W. J. Merten, C. M. Johnson, A. S. Ogg, L. L. Uhler, W. B. Crowe, F. F. McIntosh, S. L. Goodale, W. I. McInerney, W. J. Priestley, J. N. Ludwig, Jr., and T. D. Lynch.

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#### RHODE ISLAND CHAPTER

At the May meeting of the Rhode Island chapter of the American Society for Steel Treating, the following men were elected as officers for the ensuing year: chairman, F. H. Franklin; vice-chairman, Turner McPhee; secretary-treasurer, W. H. Hunt; Executive Committee: A. H. Annan, O. W. Geer, Carl Peterson, J. E. Wiggins and Thomas Wray.

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#### ROCHESTER CHAPTER

The Rochester chapter of the American Society for Steel Treating held a meeting on Monday, June 2nd, at which time Mr. Miller, metallurgist at the Pfaudler Co., Rochester, N. Y., gave an interesting talk, accompanied with slides, on the metallography of tool steels. At this meeting, new officers for the coming year were elected. They are as follows: chairman, R. B. Knight; vice-chairman, I. C. Mathews; secretary-treasurer, L. K. Marshall; Executive Committee: F. W. Arvine, and J. J. Desmond.

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#### ROCKFORD CHAPTER

At the May 16th meeting of the Rockford chapter, the following officers were elected for the coming year: chairman, Chas. Cotta; vice-chairman, G. W. Aldeen; secretary-treasurer, J. B. Frederick; Executive Committee: O. T. Muehlemyer, J. A. Nelson, J. W. Peterson, M. T. Lundstrom and Arthur Memering.

### **SOUTH BEND CHAPTER**

The South Bend chapter of the American Society for Steel Treating held a meeting on May 28th, at which time a Constitution and revised By-Laws were adopted. A program dealing with the general subject of carburizing was very ably handled by five members of the chapter, followed by a round table discussion. Those leading the discussion were: W. F. Nehouse, "Introduction: History and Theory"; F. M. Keyes, "Physical Manipulation"; J. A. Kingsbury, "Equipment"; W. J. Harris, "New Developments to be Expected"; and J. A. White, "Bibliography of Recent Literature." The following new officers were elected for the following year: chairman, R. E. Lewton; vice-chairman, V. R. Roberts; secretary-treasurer, V. A. Crosby; Executive Committee: Nelson Galbraith, L. M. Hile, J. A. Kingsbury, and J. A. White.

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### **SPRINGFIELD CHAPTER**

The following officers were recently elected for the Springfield chapter for the coming year: chairman, J. H. G. Williams; vice-chairman, Frank Mathews; secretary-treasurer, E. L. Woods; Executive Committee: V. T. Malcolm, R. J. Allen, P. W. Oliver and T. C. Kerr.

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### **SYRACUSE CHAPTER**

The Syracuse chapter of the American Society for Steel Treating held a meeting on May 22nd at Kohl's Restaurant, at which time the following new officers were elected for the coming year: chairman, S. C. Spalding; vice-chairman, L. A. Howell; secretary-treasurer, G. A. Gilger; Executive Committee: F. T. Chapman, W. Bolton, E. R. Bishop, H. J. Stagg and F. C. Raab.

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### **TORONTO CHAPTER**

The final meeting of the Toronto chapter of the American Society for Steel Treating was held on May 30th, in room 32, Mining Building, University of Toronto. The speaker for this evening was John J. Coleman, Canadian agent of Messrs. Thos. Firth & Sons, Ltd., Montreal, who read a paper on "Stainless Steel," prepared by Dr. W. H. Hatfield of Sheffield, England. The following officers for the following year were elected: chairman, J. D. Sherman; vice-chairman, O. W. Ellis; secretary-treasurer, U. C. Holland; Executive Committee: C. C. Rous, H. E. G. Watson, J. W. McBean, T. G. Holmes, W. J. Blair and H. F. Davis.

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### **TRI CITY CHAPTER**

The Tri City chapter of the American Society for Steel Treating recently elected the following new officers for the coming year: chairman, H. Brown; vice-chairman, C. A. Schoessel; secretary-treasurer, C. G. Scherer; Executive Committee: H. Bornstein and P. Bendixon.

#### WASHINGTON CHAPTER

The Washington chapter of the American Society for Steel Treating held a meeting on June 13th in the auditorium of the New Interior Department Building. D. M. Strickland, American Rolling Mill Co., Middletown, Ohio, gave an illustrated paper entitled, "Manufacture, Properties and Applications of Armeo Ingot Iron Sheets." In addition to a description of the manufacture of American ingot iron, Mr. Strickland discussed in detail the application of various protective coatings, the types of service installation where Armeo iron sheet is of particular benefit and corrosion from a practical standpoint, including corrosion tests. The following officers were elected for the coming year: chairman, Dr. H. W. Gillett; vice-chairman, P. E. McKinney; secretary-treasurer, W. H. White.

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#### WORCESTER CHAPTER

The Worcester chapter of the American Society for Steel Treating have elected the following officers for the coming year: chairman, Paul A. Porter; vice-chairman, W. C. Searle; secretary-treasurer, R. J. Phelon; Executive Committee: E. D. Clarke, L. P. Greenman, H. Klaucke, E. C. Meyer and J. Rogers.



ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR  
STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member; and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

## NEW MEMBERS

- ADAMS, R. G., (M-6), instructor, Massachusetts Institute of Technology, Cambridge, Mass.
- BABEL, E. H., (M-5), engineer, C. L. Best Tractor Co., San Leandro, Calif.
- BALLORD, H. C., (A-6), salesman, Halcomb Steel Co., New York City; *mail* 17 Arsdale Terrace, East Orange, N. J.
- BANNON, P. L., (M-5), Pacific Gear and Tool Works, 1035 Folsom St., San Francisco.
- BARRETT, M. W., (M-6), 311 Purchase St., New Bedford, Mass.
- BARROWS, S. S., (M-6), manager, steel department, Dunham, Carrigan and Hayden Co.; *mail* 2 Kansas St., San Francisco.
- BELAND, HENRY, (A-6), distributor, E. F. Houghton Co., Worcester, Mass.; *mail* Central St., Auburn, Mass.
- BENNETT, I. T., (M-6), metallurgist, Metropolitan Engineering Co.; *mail* 106 E. 19th St., Brooklyn, N. Y.
- BERGENDORF, F., (M-5), mechanical superintendent, California Cap Co.; *mail* 640 65th St., Oakland, Calif.
- BLANEY, FRED, (M-6), superintendent, General Alloys Co.; *mail* Hotel Washington, Boston.
- BOWDEN, R. K., (M-6), metallurgist, Central Steel Co.; *mail* 223 S. Cedar St., Massillon, Ohio.
- BOWMAN, H. J., (M-6), partner in firm, Martin Machine Co.; *mail* 411 W. Indiana Ave., South Bend, Ind.
- BUTTENHEIM, L. H., (M-6), vice-president, McKiernan-Terry Drill Co., Dover, N. J.
- CARLSON, H. B., (M-7), secretary-treasurer, Midwest Machine Tool and Supply Co.; *mail* 321 E. 4th St., Davenport, Iowa.
- COLEY, W. R., (M-6), shop superintendent, Leeds and Northup Co., Philadelphia.
- COOPER, A. B., JR., (A-6), salesman, Tacony Steel Co.; *mail* 27 E. Mt. Pleasant Ave., Mt. Airy, Philadelphia.
- COREY, F. B., (M-6), efficiency engineer, Pittsburgh Valve and Fittings Co., Barberton, Ohio.
- COULTER, J. V., (A-5), Midvale Steel Co., Monadnock Bldg., San Francisco.
- DAVAES, KARL, (M-5), director of Research, Phœnix, Hauptverwaltung, Dusseldorf, Eiskellerberg, Germany.
- DAVIS, L. V., (M-6), president, L. V. Davis Engineering Co., South Bend, Ind.
- DESMOND, T. M., (M-2), purchasing agent, U. S. Shoe Machinery Co.; *mail* 436 E. 6th St., South Boston.
- DRENNING, H. A., (M-3), 830 E. 146th St., Cleveland.

- DUCOMB, W. C., JR., (A-5), manager, Detroit office, American Chemical Paint Co.; *mail* 137 E. Woodbridge St., Detroit.
- EASTWOOD, JOSEPH, (S-6), president, American Forge Co., San Francisco.
- GALBRAITH, A. T., (S-6), manager of sales, Crucible Steel Company of America, New York City.
- GAST, R. F., (M-5), 114 Central Ave., Cohoes, N. Y.
- GATHMANN, MARK, (M-6), service engineer, Gathmann Engineering Co., Catonsville, Md.
- GILCHRIST, D. B., (M-4), librarian, University of Rochester, Rochester, N. Y.
- GOGLE, C., (M-5), president, Gogle Hand Forged Tool Co., San Carlos, Calif.
- GRAVELL, J. H. (M-5), president, American Chemical Paint Co., Ambler, Pa.
- HANDSCHIN, C. A., (M-5), editor, Western Machinery World, San Francisco.
- HANKS, A. A., (M-6), president, Abbott A. Hanks, Inc., San Francisco.
- HARTZ, J. L., (M-5), metallurgist, Parish Manufacturing Co., Reading, Pa.
- HAWLEY, CECIL, (M-10), superintendent, American Forge Co., San Francisco.
- HESKE, W. G., (Jr.-6), student, Lehigh University; *mail* 524 Broadway, Bethlehem, Pa.
- HOWARD, A. C., (M-6), manager, E. and T. Fairbanks and Co., East Moline, Ill.
- HOWIE, J. L., JR., (M-3), research engineer, Kellogg Switchboard and Supply Co., Chicago.
- HUTTON, T. J., (S-5), Pacific coast sales manager, Ludlum Steel Co., San Francisco.
- JONES, F. C., (M-6), superintendent of manufacturing, Victor Talking Machine Co.; *mail* 3196 Federal St., Camden, N. J.
- JOHNSON, B. H., (M-3), mechanical engineer, Keystone Watch Case Co., Riverside, N. J.; *mail* Delanco, N. J.
- JUNG, E. H., (A-6), sales manager, Cleveland Twist Drill Co., 30 Read St., New York City.
- LEONARD, G. E. (M-6), hardener, General Electric Co., Erie, Pa.; *mail* 2116 Wagner Ave., Wesleyville, Pa.
- LUDKE, LEE, (M-6), shop foreman, Lacy Manufacturing Co.; *mail* 3730 Pomeroy St., Los Angeles, Calif.
- MACGREGOR, IAN, (M-10), Sanderson Brothers and Newbold, Ltd., Newhall Road, Sheffield, England.
- MCCABE, J. H., (Jr-6), student, U. S. Veterans Bureau; *mail* 370 Ripka St., Roxborough, Philadelphia.
- MCDONALD, P. F., JR., (S-2), P. F. McDonald Co., 17 King Terminal, Boston.
- MAUCKHOFF, HENRIK, (M-5), chief chemist, International Harvester Co.; *mail* C. I. M. A., Croix Nasquehal, France.
- MEYER, J. F., (M-5), engineer, McQuay Norris Manufacturing Co., Connersville, Ind.
- MORSE, H. E., (M-5), 510 Battery St., San Francisco.
- O'LEARY, E. J., (A-5), salesman, Midvale Co., Monadnock Bldg., San Francisco.
- PARKER, C. M., (Jr-6), sales correspondent, Bethlehem Steel Co., Boston; *mail* 62 Copeland St., Roxbury, Mass.

- PRINTZ, S. E., (M-6), engineer of tests, Lehigh Valley Railway Co.; *mail* Manheim Apartments, Allentown, Pa.
- REID, JAMES, (M-6), master mechanic, Boston Navy Yard, Boston; *mail* 92 Barnard Ave., Watertown, Mass.
- RICHARDSON, M. B., (M-6), associate editor, Railway Mechanical Engineer, 30 Church St., New York City.
- ROHMER, G. E., (M-7), consulting engineering metallurgist, 10 E. 43rd St., New York City.
- RUHNS, R. B., (M-6), foreman of assembly, Linograph Co., Davenport, Iowa; *mail* 1115 24th Ave., Moline, Ill.
- SAMMIS, W. H., (A-5), power engineer department, C. H. Tenney Co., 200 Devonshire Co., Boston.
- SCHOEN, E. W., (Jr-6), student; *mail* 828 E. Maumee St., Adrian, Mich.
- SCULLY, W. F., (A-3), president, Advance Furnace Engineering Co., Box 73, Springfield, Mass.
- SHELTON, O. J., (M-4), heat treater foreman in Essex Unit, Hudson Motor Car Co.; *mail* 3519 Beniteau Ave., Detroit.
- SHOEMAKER, G. E., (M-6), metallurgist, Muncie Products Division, General Motors Corp., Muncie, Indiana.
- SMITH, HAMPTON, (M-5), southern manager, Steel Heddle Manufacturing Co., Greenville, S. C.
- SMITH, H. D., (A-4), salesman, Colonial Steel Co.; *mail* 324 Winthrop Ave., New Haven, Conn.
- TAPP, G. F., (M-5), instructor in forging, Wentworth Institute, Boston.
- TAYLERSON, E. S., (M-6), engineer in tests, American Sheet and Tin Plate Co., Pittsburgh.
- ROSEN, J., (M-5), 126 Front St., Davenport, Iowa.
- VALLADAO, CARL, (M-5), heat treater, Hall Scott Motor Car Co.; *mail* 1251 64th St., Oakland, Calif.
- VINCENT, R. E., (M-6), factory manager, Detroit Aero Metals Co.; *mail* 675 Lyncaste Ave., Detroit.
- WIDRIG, S. N., (M-6), metallurgist, Salisbury Axle Co., Jamestown, N. Y.
- WILCOX, E. A., (A-6), western manager, George J. Hagan Co., 419 Call Bldg., San Francisco.

## MAIL RETURNED

- BODKIN, J. S., Auto Strop Safety Razor Co., New York City.
- GEIS, F. R., 573 Mission St., San Francisco.
- GILL, R. L., Room 802 109 N. Dearborn St., Chicago.
- HOWELL, W. C., 1095 5th St., Beaver, Pa.
- RANSOM, F. X., 340 Leader News Bldg., Cleveland.
- ROSENBERG, F. P., Box 295, Pittsburg, Calif.
- SHAW, W. C., 1010 Quincy St., South Bend, Ind.
- WAKELAM, J. P., Y. M. C. A., Moline, Ill.
- WHITEHEAD, W. A., 7 Winter St., Arlington, Mass.

## Items of Interest

**A**S A FURTHER step in the plan to expand its scientific research facilities, announcement is made by the Carnegie Institute of Technology in Pittsburgh of the establishment of a special research bureau of metallurgy to begin its work the first of September, 1924. The express object of the new department, it is reported, is to apply to metallurgical questions the recent discoveries in the field of physics and chemistry.

The organizing of this new bureau is the second important development concerning metallurgical research that has been reported during the year at the Pittsburgh institution. The first step, it was previously announced, was the adoption of a definite program of investigation in metallurgy to be made by the department of metallurgy at the Institute in co-operation with the U. S. Bureau of Mines. Several college graduates have already been appointed to fellowships by the Institute authorities to carry out the program of research problems, the investigators to have the financial aid and assistance of an advisory board of metallurgical engineers and steel manufacturers of Pittsburgh in addition to the co-operation of the Bureau of Mines.

Attention is called to the fact, however, that the new Research Bureau of Metallurgy just organized will be a department established separately from the research investigations carried out by the department of metallurgical and mining engineers in co-operation with the Bureau of Mines.

Dr. Francis M. Walters, Jr., has been appointed director of the new bureau, and Dr. Vsevolod N. Krivobok has been appointed as an assistant, according to an announcement by Dr. Thomas S. Baker, president of Carnegie Tech. The appointment of another assistant, a specialist in X-Ray work, will be made during the summer months.

As director of the bureau, Dr. Walters will also have the title of professor of experimental physics. For the past two years he has been connected with the U. S. Bureau of Standards in Washington, D. C., as associate physicist, and he has had a wide and varied experience in the teaching field as well as in the field of applied physics. He received his bachelor's, master's and doctor's degrees from the University of Missouri. For a number of years he taught in various high schools in Missouri, and later he taught in the University of Missouri, the University of Montana, and St. John's University, Shanghai. His work has been especially in the field in spectroscopy.

Dr. Krivobok, a practical metallurgist, was educated at the Polytechnical Institute of Petrograd, Columbia University and Harvard, receiving his Sc. D. from Harvard in June of the present year.

The members of the new bureau, says the announcement, will devote their time almost exclusively to research. At first the work will be entirely of a theoretical nature, but it is expected that as progress is made, the study of a certain number of practical questions will be undertaken.

President Baker went abroad early in June to visit some of the laboratories in Europe with the special view of securing information which may be utilized in this new metallurgical work. It is reported that conferences had

(Continued on Page 34 Advertising Section)

## EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

### Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

### POSITIONS WANTED

MACHINIST with knowledge of metallography desires position. First class inspector with machine experience on machine tools and accurate automatic machine parts. Heat treatment inspection experience on tool steel and case carburized work. New England territory preferred. Address 6-10.

METALLURGIST or Assistant desires position in Philadelphia or New York district. At present employed. Four years shop experience in foundry and cupola control. Three years chemical analysis of ferrous and non-ferrous alloys. Supervision of heat treating, inspection and physical testing. One and one-half years as chemist and moulding foreman in steel foundry. Two years pyrometric and laboratory work on ball bearing steels. Technical graduate. Age 28. Single. Address 6-15.

STUDENT graduating in June, 1924, having specialized in metallurgy and the heat treatment of materials, desires to make a connection with some industrial institution. Desires to follow the art of heat treatment. Address 5-10.

TOOL HARDENER desires position. Familiar with carbonizing and all tool steels. 10 years' experience. Can give first class references. Capable of taking charge of hardening room. Location in or around New York preferred. Address 5-15.

CHEMIST AND TREATER desires position where there is a chance for advancement. Location in Philadelphia or vicinity desired. Reasonable salary. Address 5-25.

CHEMIST AND METALLURGIST desires position. Capable of handling or developing chemical and metallurgical laboratory. Experienced in microscopic examination of steel for controlling heat treating in industrial plant. Familiar with latest forging, annealing and hardening practices and equipment with pyrometric control. Capable of carrying out experimental work to improve product. Prefer Chicago location. Married. Address 7-15.

### POSITIONS WANTED

HEAT TREATER desires position. Can give references. Location preferred Cleveland, Toledo or Detroit. Address 7-5.

### POSITIONS OPEN

WANTED graduate chemist with experience in metallography and heat treatment of large sections. Address 6-5.

WANTED YOUNG MEN. High grade men to travel through the great manufacturing and industrial districts to install, inspect and test electrical instrument and temperature controlling equipment. Special consideration will be given to applicants who have had experience in handling instruments, meters, gauges, recorders, controllers, etc. Educated men preferred. Unusual chance for promotion. Write, stating experience, education, age and salary desired. Address 5-5.

WANTED RECENT TECHNICAL GRADUATE for metallurgical research on non-ferrous alloys. Good fundamental training in the principles of metallography required. In replying give education and training, industrial experience, age, religion and nationality, whether married or single, and references. Address 7-10.

### FOR SALE

FOR SALE—12 brand new Engelhard recorders of the latest type, 1200 and 1600 degrees Cent. scales. Also 2 point automatic switches for converting into double recording machines. Prices reasonable. Address 5-20.

### WANTED

WANTED—Stanton Repeated Impact Testing Machine. Second hand. Advise condition and price. Address 7-20.

WANTED TO BUY—A used Olsen Testing Machine, or similar make, 100,000 to 200,000 capacity. Must be in A-1 condition. Address 7-30.



been scheduled for him with several eminent scientists in France, England, Scotland, and Denmark.

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William C. Prendergast has been appointed district sales manager, Tacony Steel Company, with headquarters at No. 2 Rector Street, New York City. Mr. Prendergast was for fourteen years active vice-president of the John C. Vance Iron and Steel Company, Chattanooga, Tenn., a connection which he resigned to become export manager of steel products, Lucey Manufacturing Company. Subsequently Mr. Prendergast was vice-president and general manager of the Vance Import and Export Company. He joined the Tacony Steel Company in November, 1923, as manager of the Tool Steel Department, in which capacity it is understood he will continue in connection with his duties as New York district sales manager.

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The Brown Instrument Company of Philadelphia, believing that enough thermo-electric pyrometers are in use to warrant a special publication on their installation and care, have recently published a 72-page book, thoroughly covering this subject. It is entitled "Instructions for Installation and Care of Thermo-Electric Pyrometers." This includes from a practical and theoretical viewpoint, information regarding protecting tubes for thermocouples, various methods of wiring indicators and recorders, methods of eliminating cold junction errors, methods of installing couples and of checking thermocouples, wiring, or the accuracy of the instruments. Also many other points of information are given regarding conduit wiring, mounting the instruments, locating defects in the thermo-electric circuit by various means, as well as other facts, which will be of much interest to those who work with this equipment from day to day. This book contains temperature millivolt equivalents for thermocouples and conversion of Fahrenheit and Centigrade scales. It is offered free to users of pyrometers.

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R. Robert Smith, formerly with Robert H. Hassler, Inc., Indianapolis, has accepted a position as sales metallurgist with the United Alloy Steel Corporation, with offices at 1440 Straus Building, Chicago.

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A booklet has recently been published on Everdur No. 50 Metal, which has been developed by the Du Pont Engineering Company, Wilmington, Delaware. The origin, physical characteristics, working qualities, application, etc., of this metal is described in detail. The Supplee-Biddle Hardware Company of Philadelphia are the sole distributing agents for this metal and will be glad to send copies of this booklet to those who are interested.

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J. W. Rockefeller, Jr., John Chatillon and Sons, New York City, has been elected secretary of the Special Committee on Spring Research of the American Society of Mechanical Engineers.

Mr. Rockefeller has been very active in the work of this committee and is representing the American Society for Steel Treating.



## Temperature

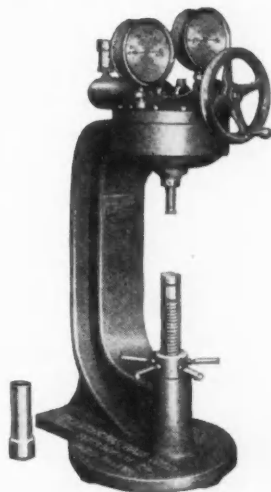
With the *F. and F. Optical Pyrometer* the temperature is measured by merely observing the object. It is accurate, simple, substantial and direct-reading.

(Write for Booklet)

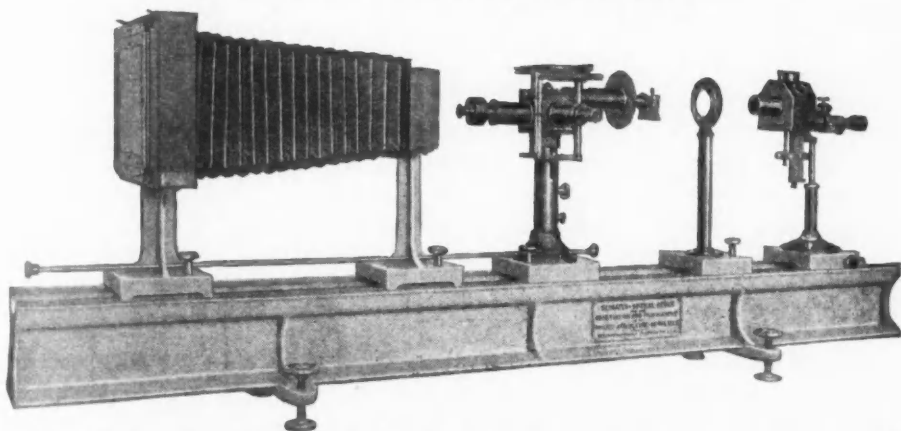
## Hardness

The *S. M. Co. Brinell Machine* is the standard machine for measuring hardness of metals and is used by the leading concerns.

Pressure is applied quickly and uniformly; a special feature prevents leakage of the hydraulic fluid.



## Micro-Structure



The *Scimatco Optical Bench* is the advanced outfit used by many of the foremost metallurgical firms for observing and photographing the micro structure of metals.

**SCIENTIFIC MATERIALS COMPANY**

*"Everything for the Laboratory"*

PITTSBURGH, PA.

When answering advertisements please mention "Transactions"

The United States Civil Service Commission announces the following open competitive examination for the position of Consulting Highway Engineer.

Receipt of applications will close July 22. The examination is to fill vacancies in the Bureau of Public Roads, Department of Agriculture, at an entrance salary of \$5,200 a year. Advancement in pay may be made without change in assignment up to \$6,000 a year. If appointment should be made to positions with headquarters outside of Washington, D. C., it is probable that the salary will range from \$4,000 to \$5,500 a year.

Applicants must have been graduated in engineering from a college of recognized standing; and, in addition, have had at least fifteen years of practical experience, of which not less than ten years shall have been in charge of important highway engineering projects, and of which at least five years shall have been in a responsible administrative position comparable in scope to that of chief engineer of a State highway department charged with handling a large program of high construction, improvement, and maintenance.

The duties of this position consist of outlining, gathering, and analyzing data relating to the administration, construction, maintenance and financing of highways and highway systems, developing the underlying principles of the science of highway engineering from administrating, engineering, and research data, and special assignments with reference to involved and extraordinary highway projects requiring unusual study and development.

Competitors will not be required to report for examination at any place, but will be rated on their education, experience, and publications or official reports to be filed with the application.

Full information and application blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or the secretary of the board of U. S. civil-service examiners at the post office or customhouse in any city.

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A group of former members of the Atlas Steel Company have entered into an arrangement with the Atlas Steel Corporation, creditors, whereby the Dunkirk plant will be taken out of receivership as soon as the local transfer can be effected. A. F. Dohn will head the new company, and others associated with him will be H. E. Nichols, F. B. Lounsberry and C. P. Burgess.

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Edgar C. Bain, formerly research metallurgist, Atlas Steel Corporation, Dunkirk, N. Y., has accepted a position in the research department of the Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.

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J. H. Williams & Co., Buffalo, N. Y., manufacturers of drop forgings and drop forged tools, have completed the transfer of their manufacturing operations from plants in Brooklyn, N. Y., and Chicago, to the home offices. After July 1 district sales offices and warehouses will be maintained at 75 Spring street, New York, and 117 North Jefferson street, Chicago. E. J. Wilcox will be sales manager of stock and P. Rigby of special products for the eastern territory with headquarters in New York, and N. P. Linde will be in charge of stock and A. C. Nuth of special products in the western district, with offices in Chicago.

# SIMONDS STEEL

CRUCIBLE

ELECTRIC

For those users who demand the most  
from their finished steel product

PERMANENT MAGNET STEELS

HIGH SPEED

BULLET PROOF STEEL for ARMORED CARS

VALVE STEELS

CHISEL STEELS

CARBON AND ALLOY TOOL STEELS

SPECIAL STEELS

BARS

SHEETS

BILLETS

SIMONDS SAW and STEEL CO.

STEEL MILLS

Lockport, N. Y.

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Several French metallurgists including Professors Albert Portevin and De Loisy have joined in an expression of appreciation of the life work of Alexandre Pourcelet, the famous French metallurgist who is now 80 years old. He is a dean of French iron and steel experts, being one of the first men on the continent to apply modern scientific methods of the study of composition of steel, during his long association with the Terre Noire company. As early as 1878, says Sir Robert Hadfield, this company published a series of brochures on the scientific aspects of steelmaking, one of which was translated into English by Sir Robert Hadfield nearly 50 years ago.

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The Pittsburgh Testing Laboratory announces the completion and occupancy of its new laboratories and offices on Stevenson street at Locust, Pittsburgh. The most improved type of testing machinery and chemical apparatus have been installed. The scope of activities of the company has been enlarged in the new quarters.

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W. M. Corse, National Research council, Washington, has accepted an invitation to deliver the third annual autumn lecture at the meeting of the British Institute of Metals, London, England, Sept. 8.

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Dr. William Campbell has been appointed first Howe Professor of Metallurgy at Columbia University, filling the new chair created in honor of the distinguished service of the late Henry Marion Howe, professor of metallurgy from 1897 to 1913, and president of the American Institute of Mining and Metallurgical Engineers in 1893. Dr. Campbell, long a member of the faculty of the Columbia School of Mines, Engineering and Chemistry, and internationally known as a metallurgist, was born at Gateshead-on-Tyne, England, in 1876. He was Carnegie Scholar in 1902 and Barnard Fellow in 1903. During the war he was a commander in the United States Navy and is now consulting metallurgist to the New York Navy Yard.

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The Worthington Pump & Machinery Corp., New York, has closed its power and mining works at Cudahy, Wis. All lines of products except the mining, crushing, cement and creosoting machinery have been transferred to other plants. The Allis-Chalmers Mfg. Co., Milwaukee, has taken over the records, drawings, patterns, pertaining to the three lines mentioned and will continue their manufacture at the West Allis plant.

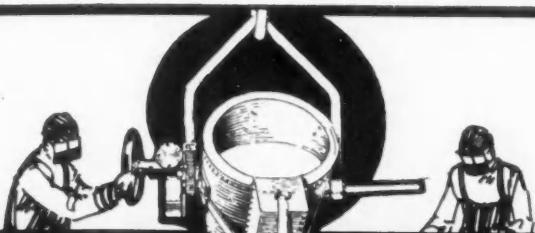
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The Ziv Steel & Wire Co., 4413 West Kinzie street, Chicago, has been appointed district representative there for the Braeburn Alloy Steel Corp., Braeburn, Pa. Gus F. Ziv heads the new representative company, and A. Ziv is vice president.

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The honorary degree of Doctor of Science was conferred on Edward Ray Weidlein, director of the Mellon Institute of Industrial Research of the University of Pittsburgh, at the sixty-eighth annual commencement of Tufts College, held on June 16 at Medford, Mass.





# FAHRITE CASTINGS

made by The Ohio Steel Foundry Co. Springfield, O.

## FAHRITE

*eliminates guess work  
in the design*  
**of High Temperature  
Equipment**

FAHRITE CASTINGS are serving in these and many other applications:

Carbonizing Boxes  
Lead Pots  
Annealing Boxes and Equipment  
Furnace Hearths, Grates and Stoker Parts  
Rolls, Chains, Links, Bars, Rails, etc., for continuous Furnaces  
Enamel Burning Equipment  
Stirring Arms and Parts for Metallurgical Roasting Furnaces  
Retorts and Tubes for Oil and other Chemical Processes  
Parts for Glassmaking Machinery, etc.

The demand for Fahrte is constantly increasing each month at the rate of 20% a month, and this demand is the result of remarkably successful performance.

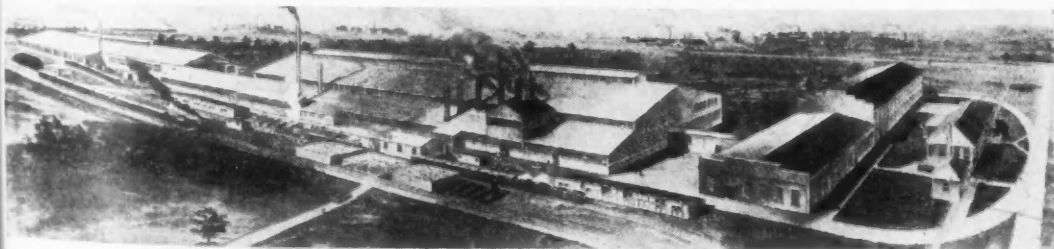
Our quantity production—made possible by the facilities offered by three large modern plants plus an engineering service that positively insures the proper use of the right grade of alloy to meet every requirement—makes possible the production of Fahrte at a new, low price level—lower than ever before reached in Heat-Resisting Alloys.

*Let us send you complete facts.*

### THE OHIO STEEL FOUNDRY COMPANY

Springfield, Ohio

Offices at: New York, 50 Church St.; Philadelphia, 22 S. 15th St.; Cleveland Union Trust Bldg.; Pittsburgh, Park Bldg.; Chicago, Peoples Gas Bldg.; St. Louis, Railway Exchange Bldg.



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F. J. Ryan and Company, Philadelphia, have announced that within the last 30 days they have received contracts from the following firms: Pratt and Whitney Co., Hartford, Conn., for an electric heat treating furnace; Reading Hardware Co., Reading, Pa., for a burner equipment for rotary brass furnaces; Thompson Wire Works, Boston, for an electric heat treating furnace; Stanley Works, New Britain, Conn., for an electric heat treating furnace; Detroit Bevel Gear Co., Detroit, for two heat treating furnaces; University of Maine, Orono, Maine, for a heat treating furnace; Westinghouse Electric and Manufacturing Co., Philadelphia, for two large ear annealers, two four-door Billett heating furnaces, and "Ryan-Austin" control equipment; Davis Brothers, Philadelphia, for "Ryan-Austin" control equipment; Isolantite Co., Belleville, N. J., for "Ryan-Austin" control equipment and Bonwit-Teller Co., New York City, for "Ryan-Austin" control equipment.

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Richard Rimbach, formerly assistant finishing end foreman of the rolling mill department of the Jones & Laughlin Steel Corporation, Pittsburgh, Pa., is now research engineer in the research department of the Union Switch & Signal Co., Swissvale, Pa.

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Leeds & Northrup Company, Philadelphia, have recently published catalog No. 90, entitled, "The Hump Method for the Heat Treatment of Steel." It contains information on the following subjects: Correct hardening changes internal structure without costly external changes; causes of failure and attendant losses; ideal conditions for correct hardening; the Hump method approaches the ideal; the Hump method and its value; a comparative record of hardening results; Hump method electric furnace and its applications and the theory of the potentiometer pyrometry.

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Ramsey Chain Co., Inc., Albany, N. Y., manufacturer of chain drives, has appointed the Morse Engineering Co., 549 West Washington street, Chicago, as its representative in the latter territory. P. A. Morse is active head of the new representative company.

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C. Harold Wills, metallurgist, president and general manager of Wills Sainte Claire, Inc., Marysville, Mich., has sailed for England, primarily to discuss developments in metallurgy with British scientists in this field.

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Dearborn Chemical Company have announced the removal of their general offices from 332 South Michigan Avenue to 310 South Michigan Avenue, 19th floor, Strauss Building, Chicago.

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On July 1st, E. W. Ehn, formerly chief metallurgist with the Timken Roller Bearing Co., Canton, Ohio, left the States, having accepted a position as consulting engineer with the Nordiska Kullager Aktiebolaget of Gothenberg, Sweden. For two years, Mr. Ehn has served as a member of the Publication Committee of the American Society for Steel Treating and has been very active in the work of this Society.

